WARFIGHTER SOLUTIONS

SUMMER 2011

NSWC Crane

SCIENCE and TECHNOLOGY

NAVSEA WARFARE CENTERS CRANE

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WARFIGHTER SOLUTIONS

NAVAL SURFACE WARFARE CENTER,
CRANE DIVISION

SUMMER 2011 — SCIENCE & TECHNOLOGY

Warfighter Solutions is the official magazine of Naval Surface Warfare Center, Crane Division (NSWC Crane), communicating the many ways in which the command and its Focus Areas harness the power of technology for the Warfighter.

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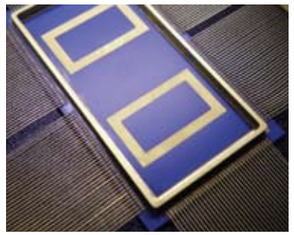
Harnessing the Power of Technology for the Warfighter

Summer 2011

WARFIGHTER SOLUTIONS

NAVAL SURFACE WARFARE CENTER, CRANE DIVISION
CRANE, IN

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WELCOME

to Warfighter Solutions

Welcome to this edition of Warfighter Solutions, which highlights Naval Surface Warfare Center, Crane Division's (NSWC Crane) Chief Technology Office and our Science and Technology (S&T) initiatives.

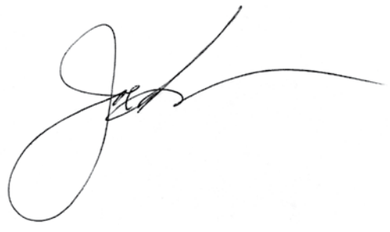
As a leading national laboratory, NSWC Crane provides the Department of Defense with the advanced Warfighter capabilities required to meet ever-changing research and development needs.

At NSWC Crane, our experts understand that collaboration is vital for technology advancement. The Chief Technology Office brings together technical experts and resources to develop solutions for complex military challenges through events such as strategic roadmapping and the Innovation Discovery Process.

Through our Science, Technology, Engineering and Mathematics (STEM) program, NSWC Crane works to build Indiana's future workforce and support S&T growth. NSWC Crane continues to expand its commitment to the STEM program through events and programs that offer exciting opportunities to engage students and educators, including several onsite workshops and camps.

Additionally, the Chief Technology Office stimulates regional and national economic growth by enabling opportunities for academia, industry and government to partner, allowing for expansion into new and diverse markets.

This Warfighter Solutions features several research breakthroughs, strong partnerships, key programs and technology innovations that occur at NSWC Crane every day. These success stories represent the dedication and enthusiasm of NSWC Crane's personnel to S&T advancement — and to keeping America's Navy #1 in the world.



Joe Gaines
Director of Science and Technology
NSWC Crane Chief Technology Officer

SCIENCE & TECHNOLOGY

at NSWC Crane

Naval Surface Warfare Center, Crane Division (NSWC Crane) has more than seven decades of trusted and proven support to the Department of Defense, the Navy and the Warfighter. Over the years, the Warfare Center's role as a leading federal laboratory has continued to evolve and expand in the area of Science and Technology (S&T). In recent years, NSWC Crane has received nearly $300 million in research, development, test and evaluation (RDT&E) funding.

The strength and value of NSWC Crane has always been in its understanding of S&T and its ability to transition technology from the laboratory to Warfighter products and capabilities—providing a clear and distinct advantage on the battlefield. An Innovation Process has been established to drive focused S&T:

S&T ANALYSIS uses strategy definition to align national security needs with NSWC Crane's technical capabilities and focus areas in Special Missions, Strategic Missions and Electronic Warfare/Information Operations.

INNOVATION LEADERSHIP aligns NSWC Crane S&T Objectives with national S&T initiatives, roadmapping events and technology opportunities to raise awareness of Warfare Center employees, facilities and technical expertise.

IDEATION & INVENTIONS discovers, extracts and protects technical ideas and inventions to strengthen and enhance NSWC Crane's technical capabilities and thought leadership.

PROPOSAL PREPARATION AND SUBMISSION implements a funding and transition strategy for each S&T initiative including preparation of proposals and pursuit of funds.

Strengthening this process are three fundamental elements:

PARTNERSHIPS – Partnering with industry, academia, and other federal laboratories is an essential component in S&T development as well as keeping current with cutting edge technology.

STEM – An increasingly complex operational environment requires a strong commitment to education in Science, Technology, Engineering and Mathematics (STEM) in order to maintain our technological edge. NSWC Crane actively partners with educational institutions, from elementary to secondary and beyond, to offer programs that advance exposure and accreditation toward careers in technical fields. This is the future of NSWC Crane's ability to provide leading edge S&T to the Warfighter.

INTELLECTUAL CAPITAL – Identifying and documenting intellectual property is critical to leveraging and exploiting NSWC Crane's expertise and innovation for the Warfighter.

NSWC Crane is an indispensable force in the collaborative S&T network and provides revolutionary capabilities to the Warfighter. As supporters of our national S&T infrastructure and active participants in the Naval Research Enterprise, the Warfare Center continues to create opportunities for technology — today and tomorrow.

S&T VISION . . .

NSWC Crane will become indispensable in a collaborative national S&T network, anticipating the future & providing revolutionary capability to the Warfighter.

S&T MISSION . . .

Create innovative S&T solutions in EW/IO, Strategic Missions and Special Missions that provide our Warfighters with a clear and distinct advantage over any adversary in an environment of affordability. Support our national S&T infrastructure and engage as active participants in the Naval Research Enterprise.

HARNESSING THE POWER

Naval Surface Warfare Center, Crane Division (NSWC Crane) stands as one of the nation's most trusted resources to protect the homeland, defeat enemies and defend our freedom. NSWC Crane is critical to the Department of Defense (DoD), providing the technical, innovative, leading-edge engineering solutions for many of the systems that protect and enable our Warfighters. The Warfare Center provides comprehensive support for complex military systems spanning development, deployment and sustainment in three Focus Areas: Special Missions, Strategic Missions and Electronic Warfare/ Information Operations (EW/IO).

Located on the third-largest naval installation in the world, spanning nearly 100 square miles, NSWC Crane's total focus is to support the Warfighter by leveraging its technical capabilities for the rapidly changing combat environment. Anchored by technical expertise, a strong work ethic and total lifecycle leadership, NSWC Crane's employees and facilities set the standard for excellence in acquisition, engineering and sustainment.

With a proven commitment to superior service and more than seven decades of experience, NSWC Crane is a premier warfare center within the Naval Sea Systems Command (NAVSEA). NSWC Crane's reach is global, and at any given time, hundreds of its more than 3,000 government employees are supporting the Warfighter around the world. NSWC Crane partners with private industry and educational institutions nationwide to develop, transition, deploy and sustain world-class Warfighter solutions. The nearly $2 billion facility also is an essential resource to Indiana, serving as a leader for economic expansion, technology-driven innovation and educational opportunity, contributing close to $2 million to the state's economy every day.

NSWC CRANE VISION . . .

Becoming DoD's premier engineering, acquisition and sustainment organization.

NSWC CRANE MISSION . . .

Provide acquisition engineering, in-service engineering and technical support for SENSORS, ELECTRONICS, ELECTRONIC WARFARE and SPECIAL WARFARE WEAPONS. Apply component and system level product and industrial engineering to surface sensors, strategic systems, special warfare devices and electronic warfare/ information operations systems. Execute other responsibilities as assigned by the Commander, Naval Surface Warfare Center.

NSWC CRANE TECHNICAL CAPABILITIES . . .

- *Strategic Systems Hardware*
- *Electronic Warfare Systems*
- *Energy and Power Sources*
- *Microelectronic Technologies*
- *Defense Security Systems*
- *Conventional Ammunition*
- *Navy Electronics Depot*
- *Special Operations Hardware*
- *Radar Component Sustainment*
- *Microwave Technologies*
- *Infrared Countermeasures and Pyrotechnics*
- *Electro-optics*
- *Acoustic Sensors*
- *Obsolescence Management*

ELECTRONIC WARFARE/ INFORMATION OPERATIONS

STRATEGIC MISSIONS ***SPECIAL MISSIONS***

INNOVATIONS

ALLIANCE CREATES SILVER LINING

Designed to foster open innovation and create a network of strategic relationships, the Radio Frequency (RF) Alliance sponsors projects that transition advanced technologies to benefit military systems and commercial applications. The group also strives to expand RF knowledge and technology transition through academic, industry and government relationships.

The RF Alliance began October 2007 following a Defense Asset Study, conducted by Indiana's Office of Energy and Defense Development, that identified a strong RF base within the state. A forum was held, which brought together multiple organizations with an RF technology focus, to share current work and to discuss how to best expand RF initiatives within Indiana.

Attending organizations, which included Naval Surface Warfare Center, Crane Division (NSWC Crane), Purdue University, Technology Service Corporation, Science Applications International Corporation (SAIC) and Lockheed Martin, helped form the RF Alliance.

The RF Alliance soon became a program of interest under the Office of the Secretary of Defense - Office of Technology Transition (OSD-OTT) and added other states and organizations to its membership base.

NSWC Crane Commanding Officer Capt. Charles S. LaSota signs Partnership Intermediary Agreement with the RF Alliance in 2009

In 2009, NSWC Crane and the RF Alliance signed a Partnership Intermediary Agreement (PIA), which facilitates interactions between Alliance members and the Warfare Center. The agreement provides access to NSWC Crane resources including experts, equipment, facilities and intellectual property (IP).

Working together, NSWC Crane and the RF Alliance strive to bridge the gap between RF technologies and operational requirements, ultimately creating more efficient technologies for the Warfighter.

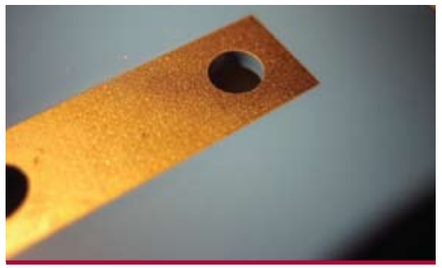
NSWC Crane plays a strong role in several projects within the Alliance and often conducts the testing and evaluations needed to certify developed technologies, processes and capabilities.

"The network of open innovation provided through the RF Alliance is truly remarkable," said Capt. Charles S. LaSota, NSWC Crane Commanding Officer. "Our partnership with the Alliance and its members is another asset to ensure we are stewards of technology for the Warfighter."

An example of a more efficient technology developed for the Warfighter through the RF Alliance is a collaboration between NSWC Crane and Omega Micro Technologies, Inc. The organizations are working together to certify a new technology and process that reduces costs and maintains reliability for weapons systems, including radars, electronic warfare (EW) and communication systems.

Several Department of Defense (DoD) program offices are interested in an improved process to reduce manufacturing costs of low temperature co-fired ceramic (LTCC) modules, which are key components in surface radar systems.

Currently, LTCC modules, which are multilayered circuits in the electrical components of a system, contain large amounts of gold. Gold is typically used in the fabrication process because of its high reliability and bonding abilities; however, by reducing the amount of gold used in the process, the circuits become more affordable for the DoD.



Plated low temperature co-fired ceramic module

Manpack radio that utilizes modules developed and certified by Omega Micro Technologies and NSWC Crane

To reduce the amount of gold and replace it with a lower cost option without compromising overall reliability and simultaneously improving performance, Omega Micro Technologies developed a proprietary LTCC plating process that uses silver in place of gold.

The developed process utilizes a multilayer ceramic substrate constructed exclusively with silver conductors that are first electrolessly plated with a nickel barrier and then followed by a thin layer of gold. The resulting external surface of the substrate is then suitable for soldering, wire bonding or brazing applications.

The plating process effectively seals the silver, thus minimizing or eliminating silver migration and yielding a highly-reliable interface for external connections to the substrate.

"The nickel-gold plating over the silver provides a high-reliability substrate, which allows for a cost savings of anywhere from 40 to 70 percent of a comparable substrate that is fabricated with all gold conductors," said Jacob Smelser, Omega Micro Technologies President.

Through the RF Alliance, NSWC Crane is evaluating and characterizing the performance and reliability of Omega Micro Technologies' plating process. The Warfare Center will conduct environmental testing and failure analysis on the developed technology, as well as offer technical guidance.

There is significant interest among program offices to use the plating process to reduce cost in surface radar systems. Following certification testing, the data will be shared with several original equipment manufacturers to determine potential technology insertion points.

UNIVERSITY PARTNERSHIP LEADS TO RESEARCH BREAK THROUGH

Offering many avenues for academic collaboration, Naval Surface Warfare Center, Crane Division (NSWC Crane) partners with numerous university experts, leading to innovation and technology breakthroughs.

One channel for academic collaboration that has produced results is the Summer Faculty Program. This program allows NSWC Crane to hire specially qualified university faculty to fill positions of a scientific, professional or analytical nature for up to 130 days.

A successful implementation of this agreement involved Dr. Russell Eberhart, who joined NSWC Crane in the summer of 2009. A professor at Indiana University – Purdue University Indianapolis (IUPUI), Dr. Eberhart is an original developer of particle swarm optimization (PSO), a computational method modeled after the social behavior of bird flocking, and is also the inventor on four other issued patents. Dr. Eberhart's extensive expertise was applied to electronic warfare (EW).

NSWC Crane Senior Engineer Patrick Shaffer enlisted Dr. Eberhart in the development of a new method to optimize the allocation of radio frequency (RF) resources. These resources use RF modules consisting of amplifiers and other transmitter components to deliver RF energy in a given, assigned spectrum. Currently, traditional resource assignment or allocation methods are limited, and the methods available to preserve signal space for priority calls underutilize the preserved space. Other methods may underserve priority signals. In the current threat environment, new methods are needed that assign resources to target more specific threat areas in near real time.

Shaffer, a retired Naval Officer and graduate of the Naval Postgraduate School (NPS), became familiar with optimal control algorithms as a result of his work supporting his NPS master's thesis in astronautical engineering. His EW experience and unique background as a naval flight officer, combined with Dr. Eberhart's expertise, led to the development of Real-time Optimization of Allocation of RF Resources — a method in which real EW systems engage and attack threats by priority given the physical attributes of the EW system and constraints of the engagement. It relates to the methods and systems for optimizing the allocation of resources using evolutionary algorithms. Since its inception, the invention has been successfully demonstrated in a laboratory setting.

"This method essentially determines a priority hit list that tells an EW system the most optimal way to allocate its resources to achieve a desired effect," said Shaffer. "We can determine a list of threats and use the algorithm to establish which threat areas need jamming resources."

The PSO approach generates optimal solutions in near real-time to under allocated resource allocation problems. Given the current performance on Windows® laptops, there is strong likelihood that additional implementation in embedded processors will result in optimal solution convergence times that are within the processing constraints of current EW systems to be considered real-time.

This invention is currently filed for U.S. patent protection and has potential utilization in many fields beyond military environments including medical and telecommunications environments; emergency response systems; and in many other situations where multiple transceivers may communicate simultaneously in a common signal space.

Through the Summer Faculty Program and similar programs, NSWC Crane is able to leverage experts from universities and apply their specific expertise to Warfighter problems. They serve as win-win partnerships for both NSWC Crane and the universities involved — university experts are able to apply their knowledge to real-world Warfighter problems, and the Department of Defense gains access to their deep expertise.

NSWC Crane hopes to increase its university collaboration and continue to leverage academic partnerships to develop technical Warfighter solutions.

"NSWC Crane is dedicated to developing the latest technologies for our Warfighter," said Joe Gaines, NSWC Crane Chief Technology Officer. "Academic partnerships are critical in making many of our programs successful."

Collection of radio frequency data at the simulated Afghan Village at Indiana's Muscatatuck Urban Training Complex

BREAKING BARRIERS

While researching current trends in the automotive industry, Naval Surface Warfare Center, Crane Division (NSWC Crane) Laser Lead Tim Bradley generated the idea of powering a laser system only on battery energy. In order to make the technology practical for the Warfighter, the system needed to be lightweight, portable and offer enough power supply to effectively breach a barrier in a constrained space.

"The automotive industry continues to discover the benefits of using lithium-ion power," said Bradley. "These same positive benefits have endless military and commercial applications as well."

NSWC Crane worked with Science Applications International Corporation (SAIC) for more than two years to design and build the portable fiber laser prototype. NSWC Crane determined the system's requirements and specifications, while SAIC supplied the laser resources, built the prototype and conducted its initial testing. Experts utilized the internal research and development funded, high-power laser and optics laboratory at SAIC's Westgate Technology Park, to develop the portable laser system.

"Our local laser and optics laboratory enables us to support NSWC Crane with technical staff and facilities to advance the knowledge of the emerging role of laser systems to defeat and

deter threats, thereby enabling our Warfighters to further extend their superior tactical advantage," said Brett Morgan, SAIC Laser/Electro-Optics Project Manager. "Reinvesting our resources to help Crane continue to move left of the lifecycle has proven very worthwhile."

NSWC Crane test setup utilizing the modified laser system at SAIC

The design includes a laser source providing optical energy, a power source and a laser-directing device that supports focusing optics in a collimating chamber, which concentrates the optical energy provided by the laser source. The system is comprised of at least one storage container to house the laser and battery power source as well as a flexible optical conduit extending from an interior of the storage container, which communicates the optical energy produced by the laser source to the handheld directing device.

"Lithium-ion is a great technology that enables innovative techniques that can be used to enhance both commercial and military systems," said Bradley. "Creating a whole system that is powered solely by these batteries is truly remarkable."

In 2010, SAIC experts successfully tested a prototype by removing the system's energy sources and powering it with only lithium-ion (li-ion) batteries for approximately 10 minutes. During the testing, the laser system cut through numerous materials including steel.

Following development and testing of the prototype, Purdue University's Burton D. Morgan Center of Entrepreneurship performed a market research study to identify possible commercialization opportunities for the laser. Identified uses of the portable laser include emergency response and rescue equipment, satellite and spacecraft meteorite protection as well as general welding and cutting equipment.

Additionally, experts at NSWC Crane currently are working with Defense Advanced Research Projects Agency (DARPA) and Massachusetts Institute of Technology (MIT) Lincoln Laboratory to create a self-protection system that will provide increased survivability capabilities to aircraft used by the nation's Warfighter.

The protection system will utilize components of the li-ion powered portable laser, previously developed by NSWC Crane and SAIC, which also allows for the capture of waste energy from the aircraft when not flying for a mission.

Bradley, with NSWC Crane's Technology Transfer Office, filed an application for a U.S. patent spring 2010. The patent, titled Portable Cutting Device for Breaching a Barrier, is currently pending.

SAIC's 3kW high-power fiber laser system

"Lithium-ion is a great technology that enables innovative techniques that can be used to enhance both commercial and military systems."

— Tim Bradley, NSWC Crane, Laser Lead

EVALUATING EFFECTIVENESS

For more than 40 years, the Warfighter has trusted Naval Surface Warfare Center, Crane Division (NSWC Crane) to design and develop infrared countermeasure (IRCM) technology for aircraft protection. As a natural extension of its expertise, the Warfare Center began modeling and simulation (M&S) efforts in the 1980s. NSWC Crane established the Navy Infrared Countermeasure Effectiveness Laboratory (NICEL) in 2008 as a core component of this research and development (R&D) capability.

NICEL's primary goal is to determine the best use of countermeasures to protect Navy aircraft from hostile infrared missiles. NICEL conducts M&S to determine the effectiveness of infrared countermeasures, primarily for the Naval Air Systems Command (NAVAIR) Advanced Tactical Aircraft Protection Systems Office (PMA-272). NICEL also performs IRCM effectiveness analysis for the Army, Air Force and some Department of Defense (DoD) contractors, as well as projects for IRCM usage to support aircraft procured through DoD foreign military sale.

One aspect that makes NICEL so unique is its full complement of M&S tools. The Laboratory has both all-digital simulators and hardware-in-the-loop simulators that can run continuously to analyze a multitude of different threat missile encounters. Models are available for numerous threat missiles, many aircraft and virtually all in-service expendable infrared countermeasures.

At NICEL, experts generate and maintain high-fidelity databases of aircraft and countermeasure information, including spectral radiant intensity and trajectory models for all Navy airborne expendable infrared countermeasures (AEIRCM), as well as many aircraft and countermeasures from the Army and Air Force.

"We're constantly chasing performance advancements — increased fidelity, faster computing — to stay on the front edge and ahead of the threat," said Brent Waggoner, NSWC Crane Lead Engineer for NICEL.

In 2010, a major breakthrough at NICEL was the development of Reconfigurable Signal Injection Missile Simulation (RSIMS). RSIMS embodies a novel and innovative approach for parallel processing that allows for real-time simulation using actual missile guidance electronics "in-the-loop." Another important aspect is that RSIMS is based upon personal computer technology, achieving higher fidelity simulations and increasing cost savings through the use of commercial off-the-shelf (COTS) technology. RSIMS has been disclosed, and an application is being developed for patent protection.

By utilizing RSIMS with real missile hardware, experts eliminate issues related to the complexity of digitally modeling the missile guidance and tracking electronics.

RSIMS will provide significant improvements to missile M&S capabilities and has two primary objectives. Its greatest utilization is in the development of IRCM to combat hostile heat-seeking missiles. However, it can also be used in missile development to evaluate performance and improve the missile's software and electronics.

The Navy, Army and Air Force collaborated to develop the RSIMS prototype. This broad participation represents an unprecedented level of cooperation among DoD M&S laboratories and industry in the area of infrared guided missile simulation. NSWC Crane initially demonstrated the RSIMS capability in May 2010, and experts anticipate actual system production and use in late 2011.

Air Force Research Laboratory (AFRL) provided significant expertise to the RSIMS project, including the development of the software for the field-programmable gate array (FPGA) based reticle processor. AFRL experts are part of the invention disclosure along with NSWC Crane personnel. The FPGA can perform multiplications and additions of large data sets very quickly and can also be reprogrammed easily.

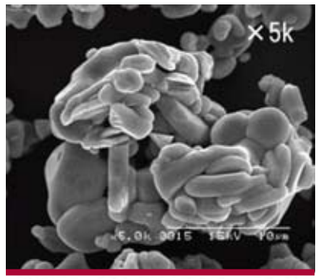
NSWC Crane partners with numerous organizations to combine efforts and best practices across services. AFRL, Army Research Laboratory, Naval Research Laboratory and Georgia Tech Research Institute are only a few of the leading laboratories that NSWC Crane partners with on major initiatives. One of NICEL's greatest objectives is to develop technologies and practices that unite experts across organizations and pool resources — leading to open innovation.

"The collaboration among services has been extraordinary," said John Bennett, lead RSIMS developer. "Each organization has a vested interest in this technology and bringing this group of experts together has generated solutions and best practices."

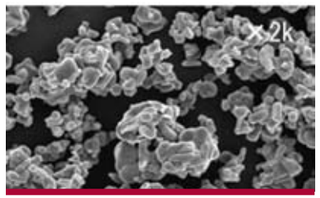
RSIMS seeker and interface electronics

Various missile seekers

POWERED BY SBIR



Scanning Electron Microscope (SEM) precursor particles from the process reactor



The spherical particles and small particle sizes shown above are critical to the performance of the cathode materials

Leveraging the Department of Defense's (DoD) Small Business Innovation Research (SBIR) Program, Naval Surface Warfare Center, Crane Division (NSWC Crane) is managing efforts to establish a domestic manufacturer of space-grade lithium-ion (Li-ion) batteries.

Li-ion batteries power networked battlefield satellites that are crucial to the nation's defense. These satellites enable Warfighters to send and receive vital information while in theater. Li-ion offers high-capacity, low-maintenance, long-duration, rechargeable and affordable power sources that significantly enhance system performance.

Primarily produced in Japan, the U.S. has little-to-no regulation or control of the production process. Missile Defense Agency (MDA), an active participant in the SBIR Program, felt it was imperative for a domestic manufacturing source to be available.

To fulfill this requirement, a solicitation for proposals entitled "Precursor Materials Manufacturing for Li-ion Batteries" was released to small businesses throughout the country. From the proposals submitted, Quallion LLC, a California-based company, was selected to receive Phase I and II grants to begin the project.

Quallion has extensive experience in Li-ion battery production for use in the medical field. The company already produces comparable formulas needed for the batteries and has proven assurance of quality control as well as more than 10 years of previous production experience.

"Establishing domestic production sources will regulate and monitor the manufacturing process as well as ensure quality control among each batch of batteries," said Dr. Harlan Lewis, NSWC Crane Power Systems Science and Engineering Senior Scientist and project technical point-of-contact (TPOC). "This process will ultimately ensure higher reliability in the satellites and aid in the Warfighter's communications."

Serving as the project's TPOC, Dr. Lewis' role is to guide and steer the technical development process. As a recognized leader in battery technologies, Dr. Lewis has more than 25 years experience and is regularly involved with the SBIR program.

In Phase I, Quallion validated the feasibility of its technical approach and transitioned into the next phase of development. Phase II of the project involved testing key equipment needed for installation of the precursor material manufacturing line. Once the equipment was certified and installed at Quallion, the project was able to transition into Phase III.

Currently in Phase III, the project's goal is to establish a domestic source, transitioning the project from federal funding to private sector or a non-SBIR government source. This will allow Quallion to advance and develop the manufacturing of the batteries.

As a leader in battery research and development, NSWC Crane will help facilitate efforts between Quallion and MDA to ensure a successful transition into domestic production.

"Producing the cell materials and manufacturing the batteries domestically will be a tremendous improvement not only for the Warfighter, but for the DoD as a whole," Dr. Lewis said. "Crane is proud to organize such efforts."

More About SBIR . . .

ALTERNATE FUNDING PROGRAMS ADVANCE FEDERAL RESEARCH AND INNOVATION

For more than a decade, Naval Surface Warfare Center, Crane Division (NSWC Crane) has participated in the highly-competitive, federally-funded Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

The programs, designed to stimulate technology advancements and provide increased opportunities for small businesses, are comprised of 12 participating federal components including Army, Navy, Air Force, Missile Defense Agency (MDA) and the Office of the Secretary of Defense (OSD).

Striving to harness the innovative talents of small technology companies, the Department of Defense (DoD) provides more than $1 billion annually to fund SBIR/STTR projects. The programs enhance economic growth while addressing federal research and development (R&D) needs.

In fiscal year 2010, the NSWC Crane SBIR program had a tremendous amount of activity. Subject matter experts (SMEs) monitored approximately 85 active SBIR/STTR projects that totaled more than $45 million.

SMEs applied their expertise in technical areas such as power and energy, radiation hardening, electronic warfare/information operations (EW/IO) and anti-tamper by evaluating more than 475 proposals for MDA, Navy and OSD.

"SBIR is an excellent venue for federal entities, small businesses and entrepreneurs," said Brooke Pyne, NSWC Crane Science and Technology Technical Project Manager. "Small businesses can strengthen their R&D capabilities and federal entities are able to address high-risk R&D needs without utilizing program funds."

THINKING OUTSIDE THE BOX

Enabling researchers to address research and development (R&D) projects with innovative and unique approaches, the Naval Innovative Science and Engineering (NISE/219) Program contributes to Naval Surface Warfare Center, Crane Division's (NSWC Crane) efforts to expand in Science and Technology (S&T).

The NISE/219 Program was created to provide means for laboratory directors to fund initiatives that directly support defense missions and provide enhancements for the science and engineering workforce. The funds are slated for investment in innovative, in-house, basic and applied research projects that promote the transition of laboratory-developed technologies into operational systems.

"Participating in the NISE Program creates opportunities to explore projects that may not be possible otherwise," said Brooke Pyne, NSWC Crane S&T Technical Project Manager. "These projects are highly innovative and reflect the talent and commitment of Crane's researchers and scientists to provide the latest and most advanced technologies to the Warfighter."

Goals of the NISE/219 program range from recruitment and retention of critical personnel to fostering creativity, exploration of cutting-edge S&T as well as maintenance of scientific and technical vitality.

The program also strives to develop enhancements for current capabilities and address future military and Department of Defense (DoD) needs. All of the program's goals reflect the importance of maintaining and improving NSWC Crane's technical competence.

"NISE helps sustain Crane as a premier Warfare Center," said Pyne. "These projects serve as an excellent opportunity to engage our Ph.D. community and other recognized technical experts in highly relevant and meaningful research aligned directly to the Navy and Crane S&T objectives."

In fiscal year 2010, more than a dozen NSWC Crane researchers and scientists dedicated their time and energy as principal investigators on strategically focused and aligned NISE/219 projects. The five projects are categorized under two S&T investment areas — Power & Energy and Spectrum Dominance.

Multiple technical papers and presentations were produced as a result of these projects, which are used to advance the technologies from the laboratory to the Warfighter.

FY10 NISE/219 PROJECTS AT NSWC CRANE

DEVELOPMENT OF ADVANCED EVALUATION AND ENHANCED SAFETY METHODS FOR LI-ION CELLS/BATTERIES

Applying proven leadership in battery technologies, NSWC Crane's Power and Energy Division Chief Engineer and principal investigator, Sam Stuart, leads a team working to establish new cell and battery configurations that will improve reliability and safety of lithium-ion (Li-ion) batteries. These improvements primarily target high-energy storage in manned and unmanned underwater systems.

"Current battery configurations do not allow for suitably achieving safe and reliable high energy density batteries using large format cells," said Stuart. "This project explores different approaches for these Li-ion cells that will improve cell balancing, heat transfer control and evaluation methods to help produce better batteries."

The second phase of this project will develop advanced cell configurations and evaluation techniques to characterize the cells with a goal of accelerating technology transition of the new Li-ion cells and battery configurations to Department of Defense systems.

TRI-BAND COLOR INFRARED IMAGER

Exploring design and development concepts for a novel multispectral, color infrared (IR) imaging system, a team led by Dr. Eric Hillenbrand is developing a tri-band camera with the ability to cover the broad spectral range of one-to-ten micrometers.

Current electro-optic and IR cameras operate in a single wavelength band including visible, short-wave IR, mid-wave IR or long-wave IR. However, to create a full, accurate scene in all types of wavelengths, multiple systems must be combined on a single platform.

"It is often unfeasible to combine multiple sensors on a single platform because of the size, weight, power and cost," said Dr. Hillenbrand. "By combining multiple wavelengths into a compact system, not only is cost and weight decreased, but situational awareness is elevated, target detection and tracking is improved and target characterization, recognition and classification is enhanced."

The already developed Duochrome camera is the beginning point for the development of the tri-band camera. The Duochrome is a single-aperture camera with two detectors capable of imaging at the upper end of the short-wave infrared and the mid-wave IR parts of the spectrum.

COMPUTER NETWORK ATTACK

Focusing on the future of cyber warfare, NSWC Crane's Electronic Warfare/Information Operations (EW/IO) Center, through the oversight of principal investigator John Vaupel, established a computer laboratory that is capable of emulating a given configuration of computer network systems. The emulated network is used to evaluate computer network attacks and develop the countermeasures to defend sensitive materials.

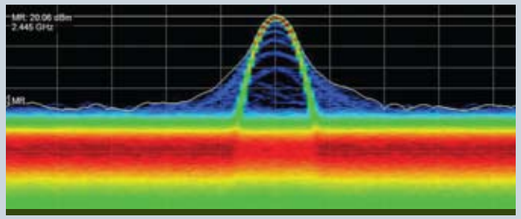
"In an age where a majority of materials are kept on computer networks, it is increasingly imperative to defend those networks against attacks," said Vaupel. "Convergence of computer network operations in the world of EW is evolving at a fast pace and continued research in this area is extremely needed."

The laboratory, developed on virtual technology, allows rapid evaluation and testing of tools and techniques that simulate real-world environments. The focus of this project is to compare open source tools with commercial tools, as well as security best practices on various computer network configurations. The testing allowed first-hand experience of vulnerability assessments and system security tools that are available to the internet community. Testing of the virtual environment was successful and is available for future computer network projects.

EFFECT OF DUTY CYCLE ON RADAR T/R MODULES AND CLUTTER ATTENUATION

In order to improve functional capabilities, many current radar systems employ active-phased array technology. The active-phased array radar concept consists of multiple antenna elements, typically numbering in the thousands, each with its own solid-state transmit and receive (T/R) module. These systems offer more flexibility and enable rapid changes to the output signal, including adjusting the rate at which it pulses, or the duty cycle.

Dynamic changes in the radar's output signal, such as rapidly changing the duty cycle, will typically result in a solid-state amplifier's active region (or junction) temperature to change quickly over time. The electrical performance of the amplifiers used in these radar systems is affected by its junction temperature. NSWC Crane Electronics Engineer, Jonathan Gregory, researches the effects of these temperature changes on the electrical performance of solid-state amplifiers to better understand the impact on future radar systems.



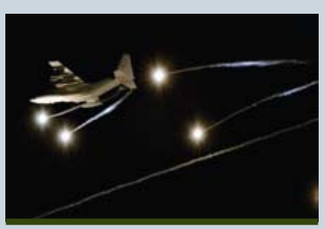
"One impact of dynamically changing the amplifier's junction temperature is a potential to have phase and amplitude instability that reduces a radar system's ability to attenuate clutter," said Gregory.

Future research will continue the investigation of the effects of transient changes in temperature and will seek to characterize the electrical changes as a means of actively monitoring an amplifier's junction temperature.

RESEARCH ON OBSCURANTS FOR AIRCRAFT PROTECTION

By researching and expanding the base materials used in decoy countermeasure obscurants, a team led by NSWC Crane Physical Scientist Mark Anderson is working to further enable aircraft survivability and self-protection against advanced military threats.

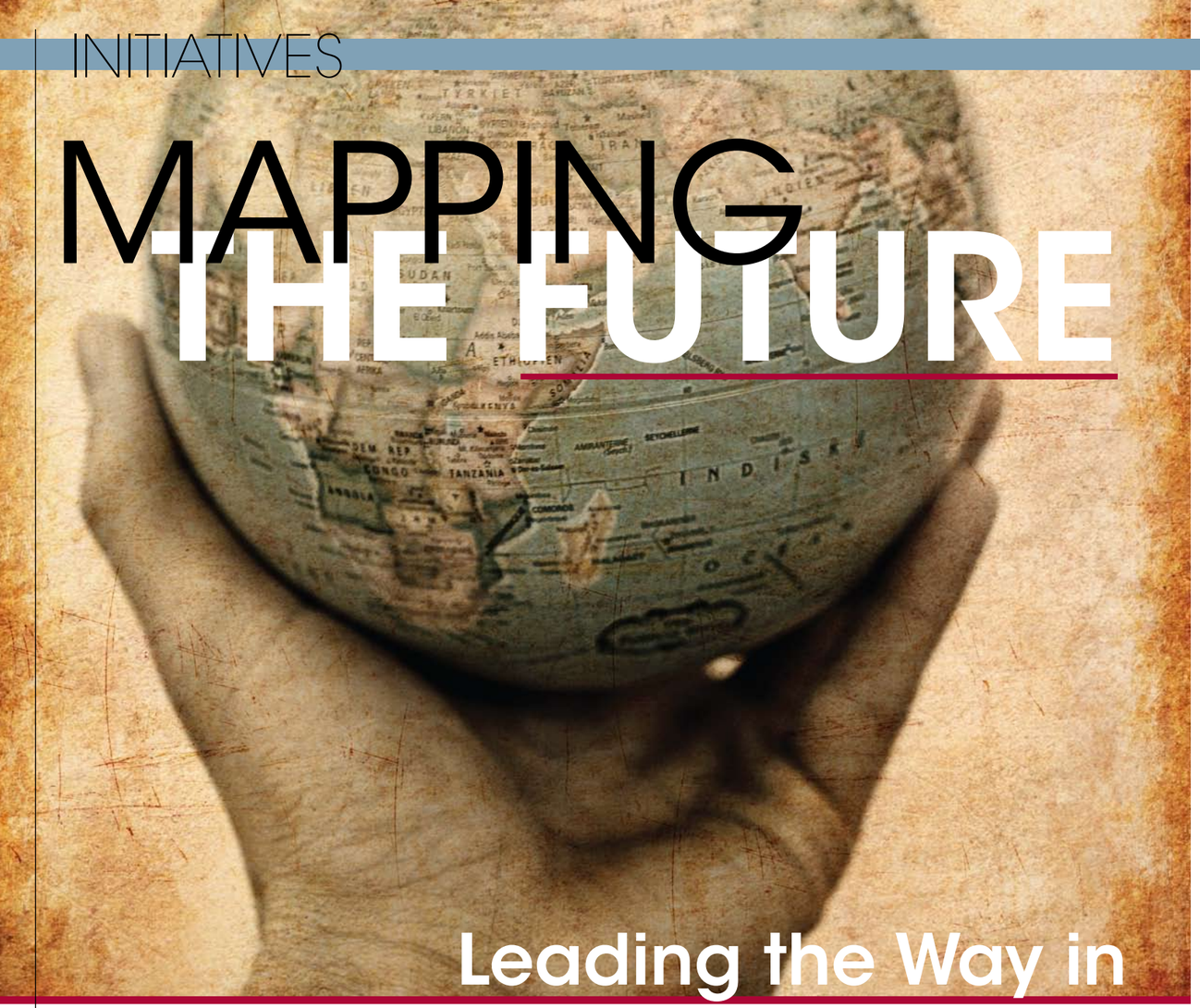
The project focuses its research on infrared, visual spectrum and ultraviolet obscurants for aircraft protection. Obscurants include any method to hide the true target in the threat sensor spectral bands by using chemical and physical methods. An opaque cloud properly placed may serve multiple purposes toward improving survivability.



"Currently, no compilation or analysis of existing materials used in decoy countermeasures is available to review," said Anderson. "By analyzing the performances of materials, we can identify concepts that prove most reliable to improve material solutions."

Ultimately, the research will improve future mission capabilities and provide safe return of pilots and aircrews.

INITIATIVES



MAPPING THE FUTURE

Leading the Way in Strategic Technology Roadmapping

Creating a dynamic, proactive plan not only enables strategic business goals, but ultimately places superior technologies and capabilities into the hands of the Warfighter.

A recognized leader in meeting and exceeding the needs of the Warfighter, Naval Surface Warfare Center, Crane Division (NSWC Crane) participates in roadmapping to identify critical assets and skills, and develop a plan that aligns Science and Technology (S&T) capabilities to meet specific gaps.

As a proven best practice to identify these gaps, roadmapping serves as an ongoing documentation process that brings together subject matter experts to focus on a specific technology. Bringing together these nationally recognized experts creates a group intelligence that is leveraged to develop a comprehensive technology strategy.

The roadmap provides a forward-looking strategy that identifies and aligns needed research to address capability gaps and enable rapid technology transition.

"Roadmapping is a validated process that produces results," said Joe Gaines, NSWC Crane Chief Technology Officer. "The events generate thinking and open the doors for cross-organizational partnerships as well as capture and document the steps needed to enhance research and development."

The development of a roadmap is a multiphase process, which includes a preliminary design period that determines the framework, vision, timing and overall organizational goals of the event. Following the background activities, experts meet to develop the actual, documented plan and follow-up implementation activities are scheduled. The document is available for updating as needed — roadmapping is an ongoing, working process.

NSWC Crane, a strong advocate for the roadmapping process, co-hosted two onsite events that identified technology capabilities and addressed technology gaps in electro-optics (EO) and high energy density systems (HEDS).

In 2009, the Special Missions Center at NSWC Crane and the Naval Research Laboratory (NRL) co-hosted the first-ever EO technology roadmapping event. The event brought together nearly 140 academic, industry, Department of Defense (DoD) and Department of Homeland Security professionals from 60 different organizations.

The 20-year timeline and plan, which resulted from more than a year of planning, knowledge gathering and discussion, serves as a resource to enable rapid EO technology transition for the Warfighter and assists in research and development; test and evaluation; and sustainment of current and future EO, infrared (IR) and laser systems.

The ability to provide the Warfighter with access to leading-edge EO capabilities is critical to maintaining U.S. military and intelligence superiority.

"Given the evolving threats facing today and tomorrow's Warfighter, EO/IR and laser technologies will play an increasingly important role in keep America's Navy #1 in the world," said NSWC Crane Commanding Officer, Capt. Charles S. LaSota. "Roadmapping is a robust example of what we need to do to remain a trusted resource of support."

Following the success of the EO roadmapping event, NSWC Crane's Strategic Missions Center hosted power and energy stakeholders from across the DoD, industry and academia to discuss HEDS.

The focus on HEDS technologies came as a direct request from Naval Sea Systems Command (NAVSEA) Commander, Vice Adm. Kevin McCoy. The event's objective was to produce a future-focused technology strategy that provided a plan to aid in the architecture of new platforms and systems, such as fuel cells, advanced energy storage and advanced energy conversions.

Experts created a 20-year outlook of new technology developments and provided insight for planning highly effective and safe energy capabilities for Navy systems.

"Our Warfighters' missions are focused on trust. They must trust that their equipment will work and last — there is no time to change batteries during combat," said keynote speaker Capt. Paul Essig, Assistant Chief of Naval Research for the Office of Naval Research (ONR). "Developing a plan now is the best way to be prepared and respond quickly for future needs."

Each roadmapping event produced a living document of recommendations tailored to guide technology transition and improvements for specific platforms and systems. Follow-up sessions are planned to continuously improve the document and provide the highest, most accurate level of input, making it a vital tool for technology advancement.

Both the EO and HEDS roadmapping events are critical pieces of NSWC Crane's S&T objectives and add substantial content for understanding and forecasting technology advancement. The efforts and resulting documents from each event play a role in developing, transitioning and supporting the systems that give the Warfighter a distinct advantage.

"Bringing together a wide range of expertise and focus is the first step to making strides for the future. Our Warfighters need the most advanced, capable technologies available and we must continuously look to the future to provide them this level of support. These roadmaps are steps in the right direction to keep our Navy on the forefront," said Gaines.

"Roadmapping is a validated process that produces results. The events generate thinking and open the doors for cross-organizational partnerships as well as capture and document the steps needed to enhance research and development."

— Joe Gaines, NSWC Crane Chief Technology Officer

INNOVATION DISCOVERY

MINING INTELLECTUAL PROPERTY

To raise awareness of the importance of intellectual property (IP), Naval Surface Warfare Center, Crane Division (NSWC Crane) collaborated with the University of Southern Indiana's Center for Applied Research (USI-CAR) to develop a method to discover and document innovation.

Coined Innovation Discovery Process (IDP), the program was created through a Navy Technology Transfer Program Office's pilot program. The program's goals are to mine IP as well as recognize NSWC Crane's technical achievements in providing advanced technologies to the Warfighter.

NSWC Crane's scientists and technical experts support the Warfighter in the areas of Special Missions, Strategic Missions and Electronic Warfare/Information Operations, providing innovative solutions that not only enhance existing systems, but also aid in the development of future capabilities. At each IDP event, scientists and engineers make presentations to panelists who then work through a creative problem solving process to identify potential inventions and commercialization possibilities.

Panel members include representatives from academia and industry, as well as local business consultants. Previous panel members included representatives from Purdue University's Technical Assistance Program, Indiana University, TechLink, FirstLink, Maryland Economic Development Corporation and Growth Alliance for a Greater Evansville.

The events are designed to quickly identify multiple inventions in strategic areas; creatively train laboratory personnel and management; and expose NSWC Crane's personnel, IP, facilities, equipment and other "shareable assets" to external partners.

"This process allows us to see the full potential of the technology developed for the Warfighter," said John Dement, NSWC Crane Technology Transfer Program Manager. "We are strengthening our capabilities for the Navy as well as discovering and documenting technology that can be transferred for commercial use or transitioned to other Department of Defense applications."

A panel views the Joint Interface Control Office Support System at an IDP event

IDP's pilot program consisted of four events in 2009 and 2010 where experts reviewed 20 projects. These events yielded 88 potential patentable inventions, 282 commercialization opportunities and precipitated the decision to continue the program at NSWC Crane.

"This first-of-its-kind program is a key component to creating a structured, disciplined process for technology innovation and sharing," said Duane Embree, NSWC Crane Technical Director. "NSWC Crane is proud to be the leader of this initiative and continue its development."

The program's model was presented at the May 2009 Federal Laboratory Consortium for Technology Transfer (FLC) national conference, the 2009 Department of Defense (DoD) Technology Transfer Integrated Planning Team (TTIPT) conference and a live demonstration was given at the 2010 TTIPT conference.

Through this type of exposure and outreach, IDP has become a model that federal research laboratories throughout the U.S. can use to discover and document IP and commercialization possibilities. Several agencies and laboratories, such as Space and Naval Warfare Systems Command (SPAWAR), Air Force and NASA have requested information in implementing NSWC Crane's novel process.

"IDP straegically brings together technical experts to assist with identifying market opportunities for Navy intellectual property and is proving to be an innovative research approach and one we hope to replicate throughout the naval labs," said Naval Research Laboratory Technology Transfer Office Program Manager, Dorothy Vincent.

The process is recognized as a recommended best practice by the Navy Technology Transfer Program, and was awarded a Naval Sea Systems Command (NAVSEA) Warfare Center Transformation Award in 2009 as well as the 2009 FLC Midwest Regional Partnership Award and the 2010 FLC Midwest Regional Coordinator's Excellence Award.

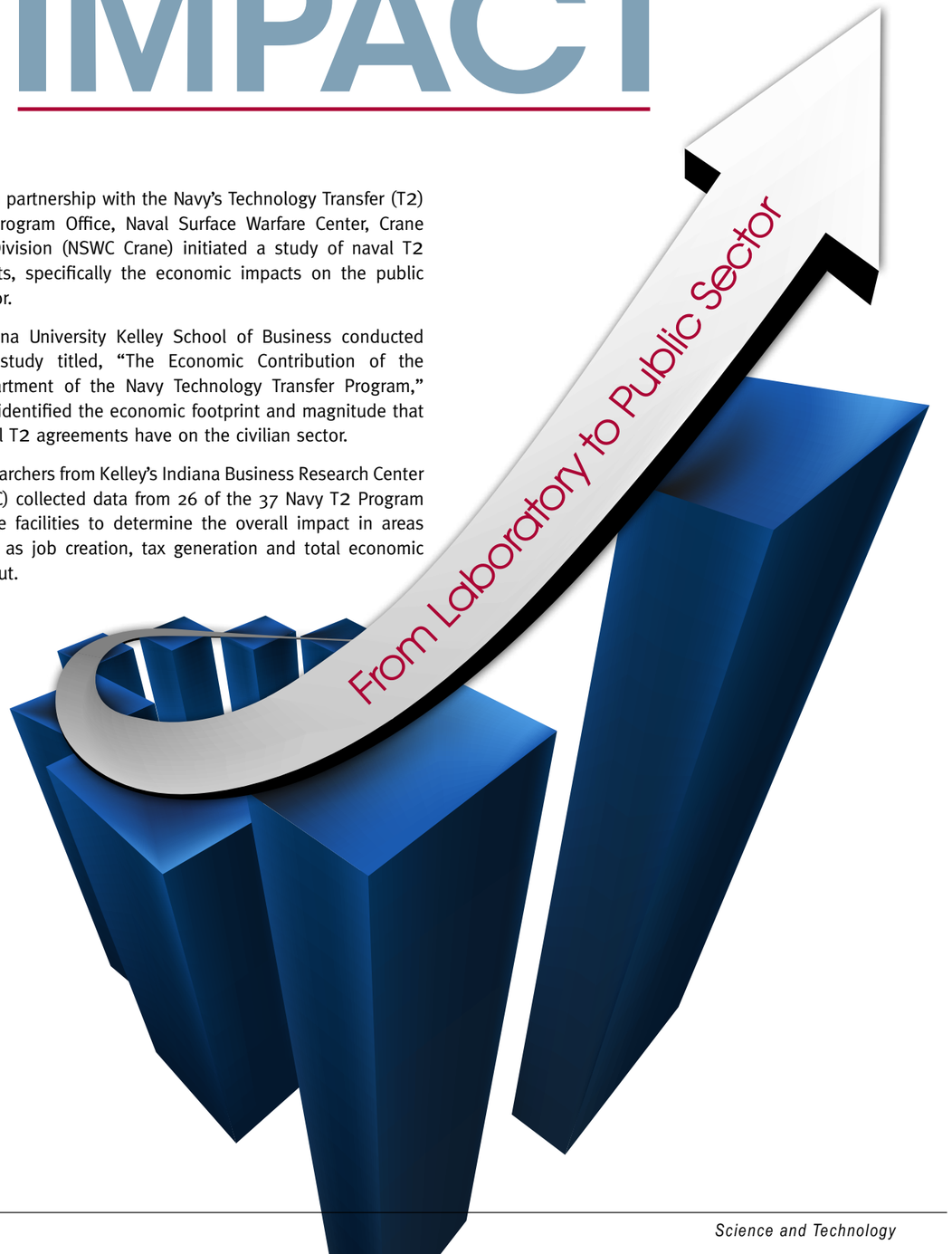
NSWC Crane Inventor and Engineer, Scott Mitchell, demonstrates the features of a lid support invention

PATENT & TECHNOLOGY TRANSFER IMPACT

In partnership with the Navy's Technology Transfer (T2) Program Office, Naval Surface Warfare Center, Crane Division (NSWC Crane) initiated a study of naval T2 efforts, specifically the economic impacts on the public sector.

Indiana University Kelley School of Business conducted the study titled, "The Economic Contribution of the Department of the Navy Technology Transfer Program," and identified the economic footprint and magnitude that naval T2 agreements have on the civilian sector.

Researchers from Kelley's Indiana Business Research Center (IBRC) collected data from 26 of the 37 Navy T2 Program Office facilities to determine the overall impact in areas such as job creation, tax generation and total economic output.



Participants included laboratories in California, Maryland, Virginia, Florida and the District of Colombia, as well as NSWC Crane. The study examined 103 naval T2 agreements that occurred among participants, of which NSWC Crane contributed three agreements.

"This report not only shows the value of technology transfer for our military personnel in the field, such as better equipment and support, but also in the civilian environment as well," said Timothy Slaper, IBRC Director of Economic Analysis and author of the study. "These agreements often generate jobs that are linked to the lab where they have agreements."

In 1980, Congress enacted a series of codes to promote T2 by providing avenues and incentives to transition technologies developed in federal laboratories to commercial markets. According to code 15 USC 3701, "technology and industrial innovation are central to the economic, environmental and social well-being of citizens of the United States."

As a leader in T2 initiatives, NSWC Crane has a robust portfolio that not only fulfills the Congressional mandate and supports the Navy, but also stimulates growth for the state of Indiana and the nation.

Recognized for intentional and strategic investments in T2, NSWC Crane's noted and award-winning strategies include intellectual property mining through its Innovation Discovery Process (IDP) and a local Partnership Intermediary Agreement (PIA) strategy. Other efforts include Educational Partnership Agreements (EPAs), Cooperative Research and Development Agreements (CRADAs), as well as Science, Technology, Engineering and Mathematics (STEM) activities.

"Technology transfer is a critical and strategic tool for NSWC Crane to achieve our goals and increase our value to the Warfighter, nation and our neighbors," said NSWC Crane Technical Director, Duane Embree. "The flipside is the value we provide to the private sector, academia and local government through access to our intellectual property, experts, facilities and equipment."

The study showed that those 103 T2 deals were directly responsible for 670 civilian jobs at private firms, universities and nonprofits. For every job that a T2 agreement directly supports, an additional three jobs are created through economic ripple effects. Taking this effect into consideration, more than 2,600 jobs were created.

In addition to job creation, the average salary of a resulting-T2 job is approximately $79,300 — about $23,000 higher than average U.S. salary. Other economic activity from the study's agreements totaled more than $545 million and generated $60 million in tax revenue.

As one of the largest employers in southern Indiana, NSWC Crane employs nearly 4,000 civilian and contractor personnel. The Warfare Center not only provides jobs, but also supports the private sector businesses by infusing more than $2 million daily into the area's economy.

In 2010, NSWC Crane was honored for its exceptional work in T2 with the Federal Laboratory Consortium for Technology Transfer (FLC) Midwest Regional Laboratory Award and the Midwest Regional Coordinator's Excellence Award. These awards recognize a federal laboratory and coordinator for extraordinary efforts that exceed legislated requirements in the furtherance of national and regional T2 activities.

NSWC Crane is home to more than 200 patented inventors and currently holds more than 192 issued and pending patents available for licensing with more than 50 other inventions in progress.

Through focused efforts and increased staffing, NSWC Crane has significantly expanded its T2 efforts. Measuring from fiscal year 2007 to 2010, disclosures increased 180 percent, filed patents increased 500 percent and issued patents increased 275 percent.

"Technology transfer is a critical and strategic tool for NSWC Crane to achieve our goals and increase our value to the Warfighter, nation and our neighbors."

— Duane Embree, NSWC Crane, Technical Director

MILITARY TO MEDICAL

Partnership Challenges Entrepreneurial Students

Taking patented military technologies and creating products for commercial use — that is the goal of a partnership between Naval Surface Warfare Center, Crane Division (NSWC Crane) and Ball State University's Entrepreneurship Center.

Through an Educational Partnership Agreement (EPA), Ball State entrepreneurial students work directly with NSWC Crane scientists and engineers to research and identify commercial opportunities for technology and intellectual property (IP) developed and patented by NSWC Crane for military use.

As a best-case scenario, a new technology is licensed and a new company is developed through the technology transfer (T2) initiative, as in the case of the simulated skin project.

Previously, the military needed an updated, realistic method to accurately test the impact of non-lethal munitions on human skin. NSWC Crane Scientist Dennis Jones developed a skin and tissue simulant, made of a gelatin composite block to represent tissue wrapped in a polyurethane sheet to mimic human skin. The simulant was patented in 2007 and currently is used in ballistics testing.

Expanding on the initial concept of the patent, two Ball State students recognized the potential of the simulant to provide more realistic models for medical personnel to practice surgical techniques. Most doctors, nurses and medical students currently practice on unrealistic, plastic body parts or expensive human cadavers.

The students, Sean Linehan and Dawn Savidge, worked with NSWC Crane to expand on the patented technology as well as interviewed medical personnel to gain specific insight for transitioning the product.

"Our research has found nothing that comes as close to simulating human skin as this product," said Savidge. "We talked to several respected people in the medical field, including one doctor who recalled he had practiced his suturing skills on a towel wrapped around a sponge."

Called "Sim Skin," the product will come in various shades and thickness to represent human aging and can be molded around artificial limbs to create numerous body parts. The students created a model leg and are working with an industry partner to develop a better prototype of the leg as well as other body parts.

The market for Sim Skin is extensive — the students' research shows that there are nearly 16,000 medical centers in the U.S., and within the state of Indiana 19 colleges and universities have medical programs.

Both students graduated in 2011 and plan to create a startup company, Forefront Industries, soon after. Linehan and Savidge would like to see Sim Skin on the market by 2012.

U.S. News & World Report ranks Ball State's entrepreneurship program as the No. 1 college class that impacts the outside world. The program includes a Military-2-Market (M2M) option where students research and identify commercial opportunities for technologies and IP developed for military use.

Ball State students Sean Linehan (left) and Dawn Savidge (right) transition NSWC Crane's skin simulant into surgical practice (prototype leg shown)

To fulfill the program's M2M option, Ball State looked to NSWC Crane for advanced military technologies. Through a T2 mandate that requires the exploration of shifting military innovations into the commercial market, NSWC Crane is able to provide access to previously patented technologies.

As a result of the partnership, the Warfare Center receives a thorough assessment of a technology's commercialization potential, while students have real-world products to base their business plan and proposals.

"This program not only benefits the students, but the licensing and production of new technologies from previous Crane work is truly remarkable," said NSWC Crane Technology Transfer Program Manager, John Dement. "Working with Ball State has resulted in several leading-edge ideas; I am excited to see what is next."

As a federal research laboratory leader, NSWC Crane offers access to its expertise and state-of-the-art facilities for economic development and job creation. NSWC Crane's research and development efforts support the Warfighter by providing capabilities and resources to advance technologies for both military and commercial use.

"Working with Ball State has resulted in several leading-edge ideas; I am excited to see what is next."

— John Dement, NSWC Crane Technology Transfer Program Manager

STEM

CONTINUES TO GROW

Science, Technology, Engineering and Mathematics (STEM) initiatives continue to grow at Naval Surface Warfare Center, Crane Division (NSWC Crane). The Department of Defense (DoD) is working to increase interest among students at all academic levels in STEM, which is designed to attract youth to technical fields and create a diverse talent pool to meet national defense needs. NSWC Crane fully supports this mission by facilitating the use of its resources to motivate, cultivate and attract the next generation of STEM talent.

To manage the increasing number of STEM-related events and programs, NSWC Crane hired its first full-time STEM coordinator, Alison Smith, March 2010. Smith is responsible for engaging and fostering partnerships with schools, industry, universities and other government agencies to create and implement programs that correspond with STEM objectives.

BRINGING RELEVANCE TO THE CLASSROOM

"It is clear we must attract the best and brightest students to the fields of mathematics and science to continue developing capable, reliable technologies," said Capt. Charles S. LaSota, NSWC Crane Commanding Officer. "To do this, we have to breathe life into our classrooms and increase students' interest and enthusiasm in these areas."

NSWC Crane's STEM program strives to bridge the gap between classroom-taught concepts and real-world applications through several activities including:

Hosting the Elementary STEM Workshop and the High School Physics and Engineering Workshop for educators. NSWC Crane offers both of these workshops in partnership with the University of Southern Indiana (USI).

Attendees meet onsite with scientists and engineers who demonstrate the use of particular NSWC Crane technologies. Teachers are introduced to inquiry-based activities, developed by USI engineering and education faculty, which directly relate to NSWC Crane technologies. Combining the inquiry-based activities and real-world applications provide students with a means of increased interest in STEM fields.

"These workshops give us tools to show students how the skills they learn in the classroom translate into real-world applications," said Tony Bacon, Mount Vernon High School teacher. "We don't always realize the high-tech jobs that are right here in Indiana — the workshops make STEM applications very relevant."

Participating in the Center for the Advancement of STEM Education Workshop. This workshop, sponsored by the National Defense Education Program (NDEP), is for educators as well as their scientist and engineer partners.

The workshop facilitates interactions of NSWC Crane scientists and engineers in the classroom, where they serve as technical mentors to students in their communities. The program anticipates that the positive interactions will inspire future generations of students to consider continuing education and careers in a STEM field.

PROVIDING NSWC CRANE MENTORSHIPS AND ENGINEERING EXPERIENCES TO STUDENTS

NSWC Crane collaborates with school corporations, professional organizations, the Office of Naval Research (ONR) and NDEP to provide students with opportunities to engage in inquiry-based STEM activities. These include:

Crane Engineers in Training, developed in partnership with USI. Based on the understanding that not all students are able to participate in after-school activities, Crane Engineers in Training allows a class of up to 30 students to visit NSWC Crane for a full inquiry- and design-based day during school hours.

NSWC Crane hired a licensed Indiana teacher to lead the program and to ensure the materials are aligned with the Indiana Academic Standards.

Sea Perch, created by Massachusetts Institute of Technology (MIT) and sponsored by ONR. This event requires students to incorporate mathematics and engineering principles to design and build an underwater robot and propulsion system, called a "Sea Perch." Students also develop a controller and analyze the effects of weight and buoyancy on their system.

Students present their design process to a panel of judges and compete against other teams in an underwater course. This event brings together local communities that support the students' efforts and strengthens the growing network of STEM supporters.

For Inspiration and Recognition of Science and Technology (FIRST) robotics. NSWC Crane supported seven FIRST robotics teams through NDEP grants. Each team had a NSWC Crane engineer acting as a coach, serving as a professional role model and providing technical guidance to students. *(continued on next page)*

"It is clear we must attract the best and brightest students to the fields of mathematics and science to continue developing capable, reliable technologies."

— Capt. Charles S. LaSota, NSWC Crane Commanding Officer

WHAT'S NEXT FOR STEM?

- Development of a virtual visit/video curriculum, highlighting NSWC Crane-specific technologies
- Participation in the Science and Engineering Apprenticeship Program (SEAP): Sponsored by ONR, SEAP allows high school students to be an apprentice under a NSWC Crane scientist or engineer for eight weeks
- Continued support of FIRST robotics teams
- Provide mentors for classes or individuals participating in science fairs
- Continued hosting of STEM workshops for educators
- Continued participation in NDEP

"Cultivating the determination and positive attitudes exhibited by these students is accomplished through outstanding mentorship. I applaud the efforts of these young students and their coaches," said Joe Gaines, NSWC Crane Chief Technology Officer. "Our contributions to the youth of today are shaping the leaders of tomorrow."

Super Summer Camp, sponsored by USI. As part of the Super Summer Classes for Kids, students ranging from kindergarten to grade nine were introduced to and engaged in STEM activities. NSWC Crane personnel led the Colorful World of Chemistry class and showed participants how color plays a role in military applications.

After learning how NSWC Crane develops flares and the tremendous protection these provide to our Warfighters, students conducted experiments to explore color properties of several materials.

Mentorship. Employees from the Warfare Center serve as technical mentors within their communities. As mentors, NSWC Crane scientists and engineers provide technical expertise, discuss real-world applications and serve as professional role models for the students. In 2009 alone, employees logged more than 1,900 hours — nearly a full work-year — through NSWC Crane's school partnership program.

For more than seven years, NSWC Crane Electrical Engineer Scott Willis, has worked with Pike Central High School students and the school's Project Lead the Way (PLTW) engineering program, offering technical support and engineering guidance.

Most recently, the students constructed a lightweight disaster relief shelter that is both inexpensive and easy to assemble and disassemble. Of the 1,200 applicants, Pike Central was selected as one of 14 Lemelson-MIT InvenTeams — a program that grants selected high schools up to $10,000 to invent technological solutions to real-world problems. This is the first Indiana school to be selected for the prestigious award.

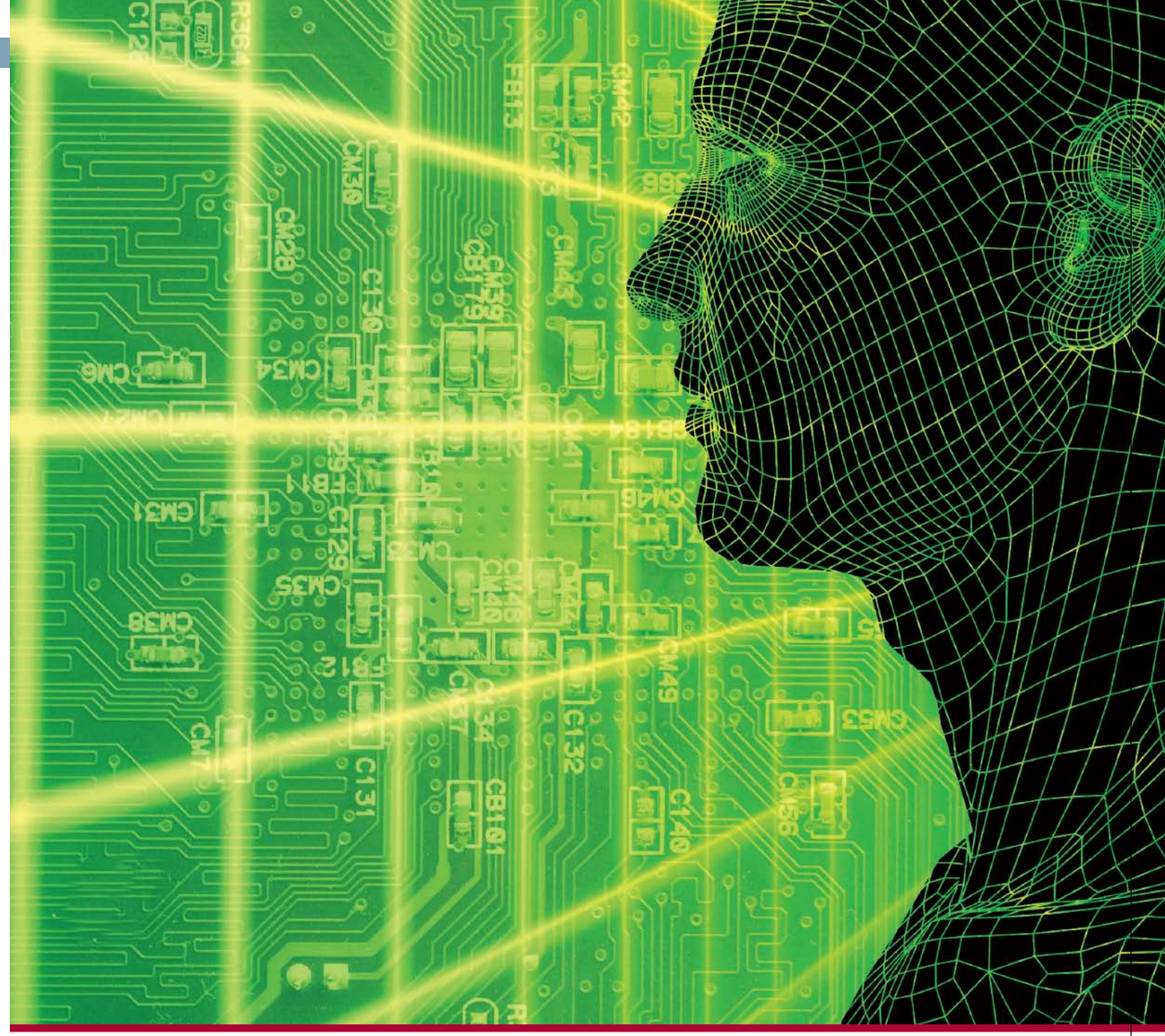
"The enjoyment the kids feel from participating is what motivates me to mentor year after year," said Willis. "I am continually impressed with the ideas they generate and the dedication they exhibit on the projects."

Extended partnerships. NSWC Crane also is engaged in several national partnerships. One includes an extended collaboration with the Admiral Hyman G. Rickover Naval Academy in Chicago. Students participate in a summer camp aimed to expose them to NSWC Crane technologies and engage them in relevant, inquiry-based STEM activities.

NSWC CRANE COMMITMENT TO EDUCATION

NSWC Crane has a long history of partnering with academia and is dedicated to increasing student interest in STEM disciplines through meaningful mentorships and by providing access to experiences such as Sea Perch, FIRST, onsite and virtual visits.

"Our employees are already very committed to engaging youth in Indiana communities," said Smith. "My hope is that through our growing programs, we can continue to increase the quality of the time spent with students and educational professionals."



INTELLECT

LEGACY of LEADERSHIP

A Resident Expert's Extensive Career in Pyrotechnics and Infrared Countermeasures

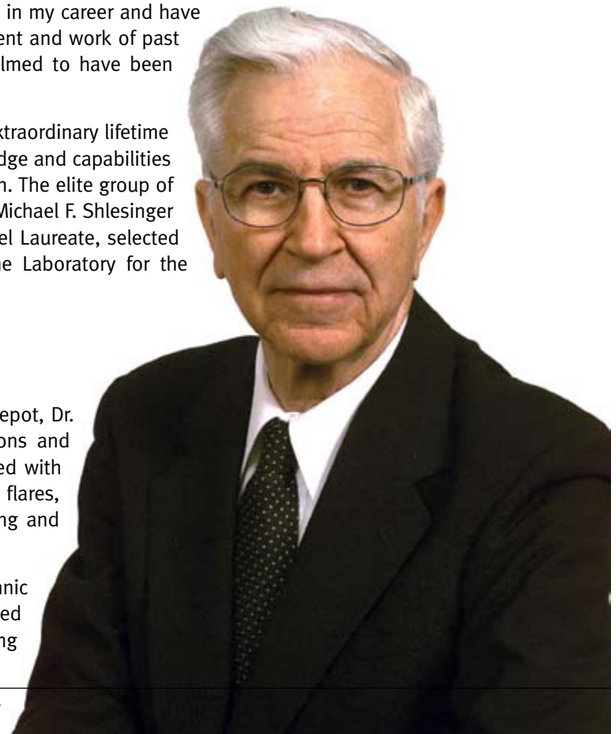
With a career that spans more than half a century, Dr. Bernard Douda of Naval Surface Warfare Center, Crane Division (NSWC Crane) has a long list of achievements, including more than 200 technical reports, eight papers in refereed journals, 13 filed patents, a published technical book and most recently the 2010 Dr. Fred E. Saalfeld Award.

Dr. Douda was honored with the award November 2010 in a letter from U.S. Navy Rear Adm., Chief of Naval Research, Nevin P. Carr, Jr., acknowledging his major contributions to the research, development, test and evaluation of pyrotechnics and groundbreaking work in the field of military infrared countermeasures (IRCM).

With an already notable list of honors and awards, receiving the Dr. Fred E. Saalfeld Award has special meaning to Dr. Douda. Aside from being the highest honor given by the Office of Naval Research (ONR), Dr. Douda personally met Dr. Fred E. Saalfeld, whom the award honors.

"I was fortunate enough to meet and become friends with Fred early in my career and have always been impressed by his work," said Dr. Douda. "Given the talent and work of past recipients of this award, I am exceptionally humbled and overwhelmed to have been selected."

The highly selective award recognizes a naval research scientist for extraordinary lifetime achievements in science that contributed substantially to the knowledge and capabilities of the Department of the Navy, Department of Defense and the nation. The elite group of past winners includes Dr. Michael Tinkham of Harvard University, Dr. Michael F. Shlesinger of the ONR's Physical Sciences Division and Dr. Jerome Karle, a Nobel Laureate, selected for his direct methods to determine crystal structures while at the Laboratory for the Structure of Matter of the Naval Research Laboratory.



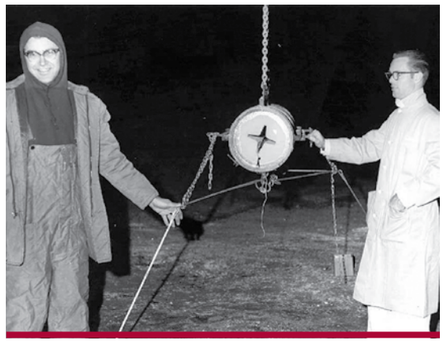
HIS EARLY WORK

Early in his career at NSWC Crane, then named Naval Ammunition Depot, Dr. Douda focused mainly on the chemistry of pyrotechnic compositions and the development of pyrotechnic devices. His research was associated with output and performance of compositions used to make illumination flares, colored flames and obscuration devices for signaling, target marking and screening.

In 1967, Dr. Douda's workload shifted to research involving pyrotechnic flames, specifically the illuminating flame. Additional research included the study of visible and infrared emission spectroscopy of illuminating flames, with emphasis on constructing models to simulate flare behavior under changing conditions.

Continuing as an innovator in the world of pyrotechnics, Dr. Douda helped establish the biennial U.S. International Pyrotechnic Seminars in 1968. He has since served on the steering committee and is currently the president.

Parallel to his ongoing, independent research at NSWC Crane, Dr. Douda received his Ph.D. in physical chemistry from Indiana University in 1973. Much of Dr. Douda's research focused on understanding basic phenomena of flames and pyrotechnic reactions. He used the theory of radiative transfer and spectral line broadening to address problems during his research.



RELATIONSHIPS ABROAD

As an advocate for international relations, Dr. Douda was instrumental in cultivating information exchange collaborations between the U.S. and other nations. He has served as the U.S. national point-of-contact for The Technical Cooperation Program (TTCP) for Pyrotechnics for the key research area of Smokes and Incendiaries since 1982. TTCP is a forum for defense science and technology collaboration between Australia, Canada, New Zealand, the United Kingdom and the U.S. It is the largest collaborative science and technology organization in the world and serves to enhance national defense and reduce costs by fostering cooperation within the science and technology areas needed for conventional national defense.

Additionally, Dr. Douda has served as the U.S. Navy representative on North Atlantic Treaty Organization (NATO) for SG-II IRCM Protection since 1980. He also was a U.S. Navy participant on Joint Aircraft Survivability Office tri-service committee on Infrared Expendables; the U.S. Navy principle on the Technology Panel for Electronic Warfare Joint Service Committee on Infrared Expendables; as well as the U.S. Navy Infrared Expendables representative on Military Sensing Symposia Specialty Group on IRCM Program Committee.

Most recently, Dr. Douda served on the International Steering and Organizing Committee for the sixth International Heat Flow Symposium on Energetic Materials and was the co-chairman for the 28th, 31st, 33rd and 35th International Pyrotechnics Seminars.

Aside from Dr. Douda's primary interest in the research and investigation of pyrotechnics and infrared decoy flares, he is internationally recognized through his placements and appointments to editorial boards and professional memberships. He worked as an associate editor of Pyrotechnics by Alex Hardt as well as a reviewer of "Pyrotechnic Chemistry," a book published by the Journal of Pyrotechnics, where he also serves as a member of the editorial board. He also is on the editorial board for Propellants, Explosives, and Pyrotechnics.

AWARDS, HONORS AND MENTORING

As a world-renowned thought leader, Dr. Douda has collected an array of awards and honors from the science community and government. In 2005, he was named a Distinguished Hoosier by Indiana Gov. Mitch Daniels and also received the Indiana Outstanding Older Worker Award. The American Society of Naval Engineers (ASNE) honored him in 2003 with the Harold E. Saunders Award for his significant contribution to naval engineering and outstanding career achievements in research development and production of pyrotechnics. The Association of Old Crows (AOC) presented him with the Distinguished Service Award and also inducted him into the Electronic Warfare Technology Hall of Fame in 2002.

Despite having international recognition and a long list of awards and honors, he remains modest. Co-workers and friends alike agree that he is exceptionally humble and even has become an unofficial mentor to many employees at NSWC Crane. Dr. Douda believes mentoring fellow colleagues not only advances the workforce of NSWC Crane professionally, but also secures the Warfare Center's future in pyrotechnics technology and research.

"It is important for me to have replacements for all the international committees and organizations that I currently work with," said Dr. Douda. "Through mentoring I have been able to recognize and recommend individuals I think are perfect for the job of keeping those lines of international communication open."

INTELLECT

ENABLING OUR PEOPLE

Recognizing that continuing education is essential not only to the personal development of employees, but also for providing leading-edge technical support to our nation's Warfighters, several educational programs designed to encourage employees to pursue higher education are available at Naval Surface Warfare Center, Crane Division (NSWC Crane).

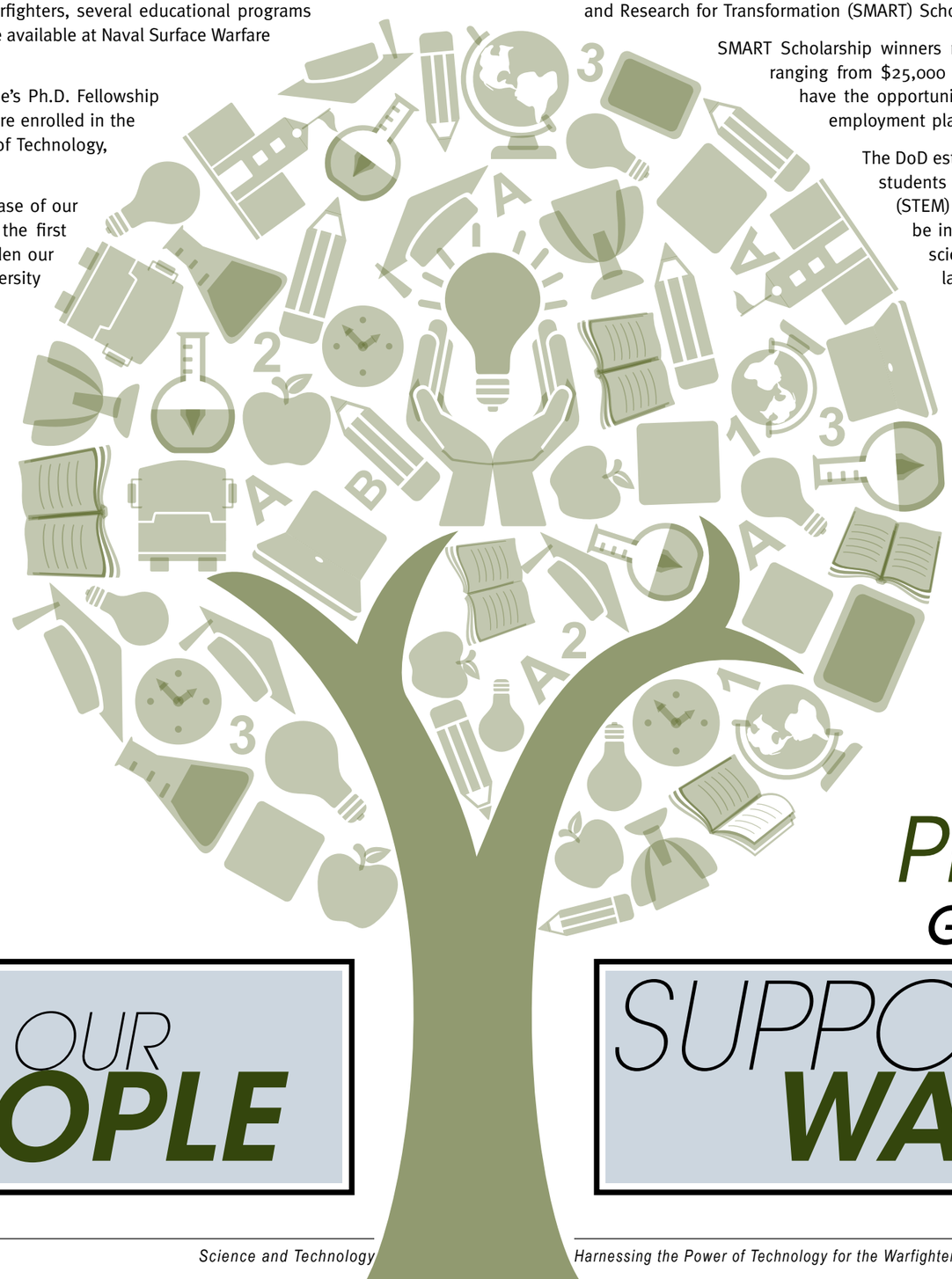
In 2007, four candidates began their doctoral studies through NSWC Crane's Ph.D. Fellowship Program. Now nine students, primarily in engineering and sciences fields, are enrolled in the program. Students are located at Vanderbilt University, Air Force Institute of Technology, Purdue University and Indiana University.

"Having students in different locations not only expands the knowledge base of our employees, but also puts Crane on the map. These employees become the first contact for many potential partners, which over time can allow us to broaden our depth of support to the Warfighter," said Dave Acton, NSWC Crane University Liaison.

NSWC Crane's Ph.D. Fellowship Program allows employees to attend a university full time and is designed to foster greater participation in doctoral-level education that directly supports one or more of its three focus areas — Special Missions, Strategic Missions and Electronic Warfare/Information Operations. NSWC Crane provides the funding for the employee's fees, tuition, books and salary and requires a strong commitment from each participant.

Selection for the program is highly competitive; each candidate participates in an in-depth interview process, must have an education plan approved by the intended university and pursue an area of concentration related to one of NSWC Crane's focus areas. Potential students work directly with their management teams to create a plan and maneuver through the selection process.

In May 2010, the program honored its first graduate, Dr. Matthew Gadlage, from Vanderbilt University's School of Engineering.



SUPPORTING THE WARFIGHTER

Ph.D.s GROW EXPONENTIALLY

In addition to the Ph.D. Fellowship Program, NSWC Crane participates in the Department of Defense (DoD) Science, Mathematics and Research for Transformation (SMART) Scholarship.

SMART Scholarship winners receive full tuition and book allowances, as well as an annual stipend, ranging from $25,000 to $41,000, depending upon prior educational experience. Winners also have the opportunity to participate in paid summer internships and mentoring, and receive employment placement assistance upon graduation.

The DoD established the SMART Scholarship to encourage undergraduate and graduate students to pursue careers in Science, Technology, Engineering and Mathematics (STEM) disciplines. The hope is to provide this opportunity to students who will be inspired to pursue these fields of study, and additionally, that more civilian scientists and engineers will be compelled to work at DoD facilities and laboratories, such as NSWC Crane.

"This particular scholarship is a win-win for NSWC Crane and its scientists because it serves as an incentive for individuals who demonstrate an aptitude in science or engineering to continue to grow in their field," said NSWC Crane Chief Technology Officer, Joe Gaines.

Currently, NSWC Crane is home to more than 50 Ph.D.s, with an additional 16 working full time toward their doctorate through either NSWC Crane's Ph.D. Fellowship Program or SMART.

NSWC Crane strives to enable its employees to pursue educational opportunities to ensure that the Warfare Center stays at the forefront of the latest technologies and innovations. Graduates are able to bring the knowledge and skills they learn in the classroom and apply them to current and future NSWC Crane initiatives.

PROGRAM HONORS FIRST GRADUATE - MATTHEW GADLAGE

In May 2010, Dr. Matthew Gadlage graduated from Vanderbilt University's School of Engineering, becoming Naval Surface Warfare Center, Crane Division (NSWC Crane) Ph.D. Fellowship Program's first graduate. His studies focused on the effects of radiation on microelectronic devices, specifically in space applications.

During his studies, Dr. Gadlage published more than 30 papers and received several prestigious awards, including best paper at the 2007 European Conference on Radiation Effects, 2009 Best Research Paper published by a Vanderbilt University School of Engineering student and the 2010 Institute of Electrical and Electronics Engineers/Nuclear and Plasma Sciences Society (IEEE/NPSS) Paul Phelps Award.

"Matt's expertise and dedication to radiation science research is an asset to our work at Crane. He set a precedent for the Ph.D. Program and his achievements demonstrate the abundance of time and effort he has already contributed to the field," said NSWC Crane Chief Technology Officer, Joe Gaines. "His research will aid not only current engineering support, but also pave the way for next generation systems."

Before entering the Ph.D. Fellowship Program, Dr. Gadlage worked in NSWC Crane's Strategic Missions Center as a member of the Radiation Sciences Branch. Since returning from school, he has continued to apply his research of radiation effects in respect to cosmic and solar rays, testing space-based weapon systems.

"The program provides a great opportunity for Crane employees to pursue their higher-educational goals," said Dr. Gadlage. "Without the program, some employees might not have the means to continue their education, resulting in the potential loss of some exceptional researchers."

SMART SCHOLARSHIP - GRACE SHIH

Selected for the Department of Defense (DoD) Science, Mathematics and Research for Transformation (SMART) Scholarship, Grace Shih is earning her Ph.D. and preparing for her future with the DoD.

Shih studies materials science and engineering at the University of Arizona, and will join the Naval Surface Warfare Center, Crane Division (NSWC Crane) workforce upon her Ph.D. completion May 2012. Her studies focus on advancing alternative energy, and she concentrates her research on the fabrication and utilization of quantum dots to increase efficiency in solar cells.

Through the SMART scholarship, Shih spent summers 2008 to 2010 completing internships at NSWC Crane, the Naval Research Laboratory (NRL) and Purdue University. She used state-of-the-art equipment at these facilities to perform research, conducting nano-electronic measurements on solar cells.

NSWC Crane invited Shih and her research advisor, Dr. Barrett Potter, to attend the 2009 Office of Naval Research (ONR) Naval Energy Forum. As part of the forum's Energy Challenge, they submitted a paper titled "Optoelectronic Nanocomposite Materials for Thin Film Photovoltaics," which was awarded one of nine $100,000 research grants.

"The SMART Scholarship affords me the opportunity to conduct research at a variety of laboratories and work with many experts in alternative energy," said Shih. "No other program could better prepare me for a career with the DoD."

Shih hopes to use her knowledge and experience gained through the SMART Scholarship to further advance NSWC Crane's leading research capabilities in alternative energy.

RESEARCH

The Canonical Decomposition Fuzzy Comparative Approach to **Assessing Physical Architectures**

by Jason P. Dauby

The impacts of decisions made during the selection of the system architecture propagate throughout the entire system lifecycle. Systems engineering efforts produce a successful artifact only insofar as the functional architecture successfully captures the needs of the user and the physical architecture represents a stable and achievable form. The challenge for systems architecting is to perform a realistic assessment of an inherently ambiguous system concept.

Subject-matter experts perform their intuitive interpretations and heuristic assessments quickly. These methods often guide system development in the right overall direction, but they are also subjective and exhibit poor repeatability. Probabilistic assessments such as Bayesian Belief Networks and the Evidential Reasoning form of Multi-Criteria Decision Making are vulnerable to subjectivity in the way probabilities are assigned to decision nodes. Traditional analytical assessments dismiss part of the complexity in a system by assuming severability between system components. This eliminates the ability to study coupling variables in a system.

A suitable assessment methodology must be stable, repeatable, and analytically rigorous so as to be peer-reviewable and defensible within the system development community. The goal is to retain the ability to examine coupling variables in a system architecture, thereby making the assessment more realistic. Finally, the methodology to be developed must be capable of tolerating ambiguity in the architecture description. In summary, the methodology must facilitate enough specificity to examine inter- and intra-system coupling while being general enough to apply to an entire genre of solution types.

The hypothesis for this research is that an architecture-assessment methodology capable of achieving these objectives is possible, and that the Canonical Decomposition Fuzzy Comparative (CDFC) approach is one such methodology. The methodology consists of four elements:

1. *Extensible modeling*. The extensible modeling concept facilitates the exchange of data between model resolution levels.

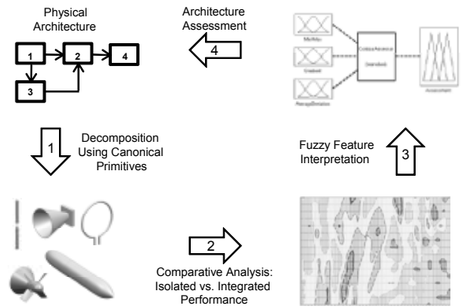
2. *Canonical design primitives*. Canonical design primitives are basic representations of system component technologies.

3. *Comparative analysis*. Because of ambiguity in the system design, conclusions are reached based on comparative measures between baseline assumptions and canonical embodiments.

4. *Fuzzy inference*. Fuzzy inference systems provide a mapping from system response features to fuzzy sets describing the architecture assessment.

The research approach has been to identify and refine the underlying elements described above, integrate them into a cohesive methodology, and apply them in the assessment of candidate architectures for the physical system. A graphical overview of the CDFC methodology is provided in figure 1.

Figure 1. Graphical overview of the CDFC methodology



The primary contribution of this research is the ability to more effectively refine and select system architectures for subsequent development. By more objectively and realistically assessing system concepts, the strongest ones can be identified, thereby increasing the likelihood of development success. Additionally, the decomposition of physical architectures using canonical design primitives gives systems architects access to a wide range of computational tools that were previously reserved for the detailed-design community. Computational techniques such as finite element analysis and method of moments allow for higher-fidelity analysis of system architectures to expose inherent integration and design sensitivities. By studying environmentally coupled performance of system elements in this way, certain emergent attributes can be exposed during the early stages of architecture development. Leveraging existing analysis tools has many advantages. A number of existing academic and commercial tools are widely accepted and rigorously validated within their specific disciplines. Usage of common tools reduces the need for validation of the tools themselves and establishes an initial level of buy-in from stakeholders. Common tools also facilitate communication between the systems engineering community and the specialty-engineering communities.

To determine the efficacy of the CDFC approach, a specific analysis involving a peer-to-peer wireless network for both air and ground nodes is underway. The network is intended to meet the high-level user need for increased situational awareness and tactical effectiveness through data exchange. The air and ground vehicles themselves represent the immediate integration environment for a supplemental system intended to accept, format, transmit, receive, and present sensor data via a secure wireless exchange between participating nodes.

The wireless system as described is complex and involves the exchange of many basic-level physical quantities. It was necessary to limit the scope of this experiment in order to determine the merits of the CDFC approach. A single system attribute is being evaluated. Range, as defined by radio-frequency link distance, is assessed based on the contributing technical performance measure of antenna gain.

Three different physical architectures have been defined and a canonical probe structure was produced. The comparative data sets differentiate between the free-space gain performance of the antenna as a baseline and the installed performance as the indicator of integration sensitivity. This data set is processed to determine regions exceeding threshold limits, average deviations, and mean absolute error. These values serve as the input variables to the fuzzy assessor which provides the overall assessment of antenna gain as a technical subattribute.

The aforementioned experiment is being conducted in an academic context, but it is believed that this research has strong potential for advancing the state of practice as suggested by its early adoption in current US Department of Defense studies. Several elements of the CDFC methodology are currently being used by systems engineers at the Crane Division, Naval Surface Warfare Center (NSWC Crane). Canonical design primitives and comparative analysis methods are being used to investigate system concepts for a potential Acquisition Category (ACAT) ID program for the Department of the Navy. Of particular importance is the fact that the CDFC elements mentioned are being used to assess electromagnetic, fluid dynamic, mechanical, and power generation and distribution aspects of each system concept. This supports the hypothesis that the CDFC methodology is broadly applicable to multiple technical domains. Extensible modeling concepts are also being used by the same study in order to leverage engineering level analyses to increase the fidelity of engagement and mission level modeling. Feedback from the use of this methodology in the aforementioned program and the academic research related to wireless network nodes will offer an evaluation of the strengths and weaknesses of the CDFC approach.

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2010 INCOSE Foundation Award Recipient

The International Council on Systems Engineering (INCOSE) Foundation announced NSWC Crane Division Subject Matter Expert, Jason Dauby as the recipient of the 2010 Stevens Doctoral Award for his exceptional research in systems engineering and integration.

A panel of INCOSE Fellows reviewed applications from a pool of highly qualified applicants from universities around the world. Applications were evaluated against three criteria: the doctoral research advances the state of knowledge in systems engineering and integration; the doctoral research provides potential for the advancement of the state of the practice of systems engineering and integration within the next five to ten years; and the rigor of the doctorial research approach.

"I am honored to receive this award from such an esteemed organization," said Dauby. "Hopefully this research aids in the successful development of advanced systems for the Warfighter."

Dauby conducted this research through his Ph.D. studies in Systems Engineering at Missouri University of Science and Technology, and he continues to research analytical approaches to assessing system architectures.

Dauby has worked at NSWC Crane for more than eight years as a radio frequency systems engineer, specializing in physics-based modeling and technology development. His experience includes the use of model-based analysis and design throughout all phases of various air-, ground- and maritime-based electronic warfare programs.

Elimination of Perchlorate Oxidizers from Red Pyrotechnic Flare Compositions

by Christina M. Yamamoto
Robert G. Shortridge
Sara Pliskin

INTRODUCTION

In 1997, the Department of Defense (DoD) was tasked to study the effects of perchlorate contamination in ground water. Ground water contamination by perchlorates has been found to be a serious problem in many areas around the world. Perchlorates are known to inhibit iodine uptake by the thyroid gland, thus lowering the level of thyroid hormone in the body. This can lead to permanent neurological damage in unborn and newborn babies. Since this study, the government has been trying to reduce or eliminate the perchlorates used in many munitions. The Environmental Protection Agency (EPA) has been monitoring the permissible level of perchlorate contamination and has recently lowered the level to 15 parts per billion (ppb). This is a strong indication that the government is moving toward a more stringent level of perchlorates and that the DoD must take an even more active role in trying to eliminate perchlorate from its munitions. Most in-service colored pyrotechnic flare compositions contain perchlorate oxidizers. Residual perchlorates from these devices may be absorbed into groundwater. This has contributed to an increase in the total concentration of perchlorate residues at various military and industrial sites, and to higher concentrations in drinking water. Accordingly, perchlorate oxidizers currently used in various pyrotechnic flare compositions are being substituted with nitrates or other oxidizers. Because these oxidizers are less reactive than those that contain chlorine, higher energy or higher specific surface area fuels are being used to make-up for the loss in energy.

Any means of eliminating perchlorates without degrading performance would be a noteworthy advancement. Naval Surface Warfare Center, Crane Division (NSWC Crane) has found a formulation that meets Navy performance specifications for the Mk124 Red Marine Smoke Illumination Signal. This formulation has been designated as RSF-4 and is currently in qualification stages. This work has been sponsored by the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP).

Recently, the U.S. Army Armament Research Development and Engineering Center (ARDEC) approached NSWC Crane to assess the feasibility of transitioning the perchlorate-free RSF-4 red flare composition to the Army's M126A1 Ground Illumination Signal, Red Parachute. The perchlorate-free replacement composition, RSF-4ARDEC, is the result of a judicious choice of magnesium fuel particle size distribution, fuel to oxidizer ratio, and weight percentage of binder. This composition will not only meet the luminous intensity, dominant wavelength and color purity performance specifications of the Navy MK 124, but can also be tuned to meet the Army M126A1 performance requirements. The elimination of perchlorates from the M126A1 is sponsored by PM-Closed Combat Systems.

CURRENT EFFORTS

Based on previous success of the RSF-4 compositions at laboratory and concept scale, experimental mixes were scaled up to 3500 grams. Several iterations of perchlorate-free compositions consisting of varying size distributions of magnesium fuel, nitrate oxidizers, a chlorine donor, and binder were initially mixed and pressed into actual scale pellets in order to fine tune the burn rates and luminous intensity output. The optimum dead loads for pressing the candles were also studied. The candles were pressed in three 30-gram increments. Performance testing of both red control flares and perchlorate-free red flares were completed for the first iteration of mixes. Both the control and the perchlorate-free mixes meet burn time and candlepower performance specifications. This iteration of mixes contains two different particles sizes of magnesium. Previous effort with this formulation has proven that the burn time can be lengthened by lowering the fuel to oxidizer ratio, by increasing the particle size distribution of the magnesium fuel, and by increasing the weight percentage of the curable binder system. Candlepower can be increased by using smaller granulation magnesium and using a lower binder volume.

For the M126A1, the compositions were pressed into two different types of tubes, kraft paper (Army) and fish paper (Navy). The current Army specification uses kraft paper. Previous work with this formulation has been performed using fish paper. Fish paper is stronger and uses epoxy coating in between the layers of fish paper while the kraft paper is more of a cardboard and easily deformed. Dead loads at 7000, 8000, and 9000 pounds were used in order to determine which dead load would provide optimal performance while allowing for complete consolidation of the candle.

Most of the tests have been performed using epoxy coated tubes. Initial tests have been performed using uncoated fish paper tubes, and they appeared to perform within M126A1 specification with very little differences in candlepower and burn time. More testing will be performed with uncoated fish paper tubes to determine whether the processing benefits of using uncoated fish paper tubes are worthwhile.

SUMMARY AND CONCLUSIONS

The preliminary results of the RSF-4 composition show promising application to current Army and Navy red colored flares. The candle burn tests meet the minimum candlepower requirement, and even exceed the performance requirement. Burn times were easily achieved. In fact, through meticulous optimization, this formulation can be tailored to meet specified burn times and candlepower requirements. It appears that the use of fish paper tubes works best with this formulation and that more studies are needed to optimize the manufacturing process. This project shows the feasibility of replacing perchlorate-containing flares with a non-hazardous perchlorate-free composition.

Future work for this project includes complete Energetic Material Qualification (EMQ) for the Army qualification as well as Navy formulation qualification. Studies are currently on-going to assess the ignition sensitivity of the perchlorate-free formulation in addition to thermal characterization and aging studies.

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Single-Event Test and Analysis of SerDes Devices

by Sarah Armstrong

The ability to transmit data at high speeds across an interface is critical to all modern communication devices. In order to meet this need, high-speed serial communication protocols have been developed – the common universal serial bus (USB) is a ubiquitous example. The enabling integrated circuit for the continued advancement of high speed and high performance serial communication has been the Serializer/Deserializer (SerDes) class of circuits. SerDes devices provide fast data transfers (in excess of 10 Gbps) across chip-to-chip, board-to-board, and backplane interfaces. These circuits have become essential building blocks for high performance systems, including space and weapons systems. A block diagram of a SerDes is shown in Fig. 1.

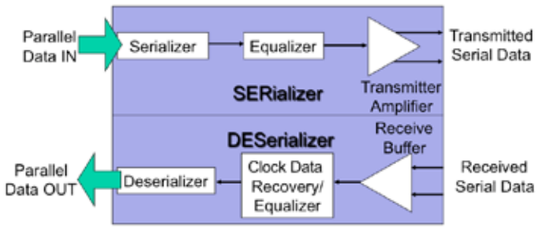

Figure 1: Simplified block diagram of a SerDes system.

Radiation sensitivities in deep-submicron CMOS SerDes must be considered in the design and implementation of SerDes devices intended for use in a hostile environment such as space. The SerDes circuitry is made up of high-speed analog/RF circuitry operating at I/O voltages (i.e. 1.8V and higher), analog/mixed signal (A/MS) circuitry operating at core voltages (i.e. 1.0V and lower), and digital circuitry operating at core voltages. This mix of circuit types on a single integrated circuit presents design challenges that are compounded when radiation tolerance is considered.

Radiation-hardening-by-design (RHBD) is the practice of using circuit techniques and layout configurations to mitigate errors caused by ionizing particles. These techniques vary with circuit type and expected radiation environment. Digital RHBD practices for single event effects (SEE) are well defined [1] but A/MS RBHD technique development has lagged. Prior work has shown that analog response depends on the circuit structure at the location of the single-event strike [2]. Therefore it is important for the circuit designer to be aware of the resulting temporal characteristics of the event to best mitigate errors.

TESTING

Single-event testing of highly-scaled state-of-the-art integrated circuits, such as SerDes for SEEs, is one of the more challenging problems facing the radiation-effects community today. Error rates can be determined using a bit error rate tester (BERT), but when the temporal characteristics of the error are of interest, a time-domain error-identification solution must be used. The means to recording time-domain results utilizes an oscilloscope triggered on the error event itself using pre-defined criteria based on tolerances of a specific system. This triggering method is preferred in heavy-ion test environments. However, error events can be overlooked if the error response is different than expected (e.g., the occurrence of a phase shift when triggering off of a missed bit).

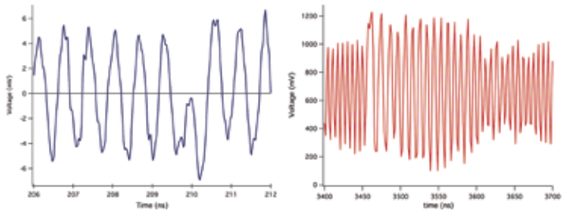

Fig. 2: Error types as seen in laser testing – a bit-error in a SerDes device (left) and a phase error in a PLL (right). These errors would be indistinguishable using a BERT or may be overlooked using error triggering on an oscilloscope.

Example error signatures from a SerDes circuit and a PLL are shown in Fig. 2. The waveform on the left shows a bit error, an amplitude error is shown on the right. BERT testing would indicate an error in both of these transients, but the temporal characteristics would not be recorded. An oscilloscope triggered on a bit error would not detect errors in the phase error transient and could result in an inaccurate error count.

Time-domain, laser-based SEE test approaches are being developed for high-speed SerDes and phase-locked loop (PLL) devices as alternate solutions to supplement the shortcomings the above procedures. Triggering the oscilloscope on the applied event (laser pulse or accelerated ion) provides a known event time and allows the clock or data signal to run independently of the triggering event ensuring all of the data cycle is tested. These advantages lead to significant flexibility in the data analysis. The time-domain approach provides the ability to quickly quantify the full range of single-event error signatures even under changing requirements and to identify unexpected circuit behavior, such as a novel error response that may not be captured using a preset triggering scheme. The test approaches are applicable to other types of high-speed circuits: analog, mixed-signal, and digital.

ANALYSIS

The testing technique results in a large data set that would be cumbersome if used only for simple error identification via scripting. The advantage lies in advanced analyses such as identifying phase dependence of errors. This type of analysis has been difficult to accomplish experimentally due to challenges in correlating frequencies of the laser and device, as had been required previously.

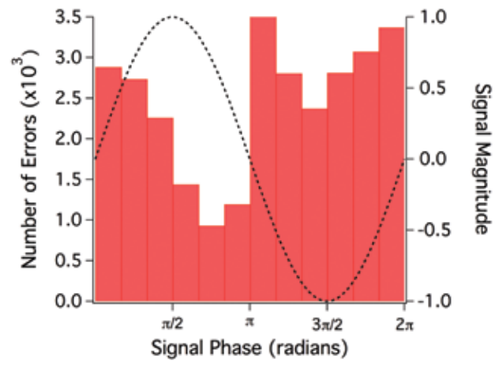

Figure. 3: Histogram of errors with respect to time in the data cycle (left axis) with an overlaid data cycle for correlation (right axis). Figure from [3].

The determination of the phase dependence of single-event vulnerability begins in the post-processing of data. As errors are identified, analysis of the transient data returns the time in the data cycle at which the laser struck the device. The error-causing strike times are binned in a histogram to correlate error times with characteristics of the data cycle. Figure 3 shows the data cycle with corresponding times of errors for OUTP of a single location in a scan of the differential-pair transistors, T9 and T10 in Fig. 4. The error profile indicates the sensitive time in the cycle to be during the peak of the data signal – when T9 or T10 is off. Using this information, it is possible for the designer to make an informed decision as to how the circuit response can be improved using RHBD techniques such as additional capacitance or differential charge collection [4].

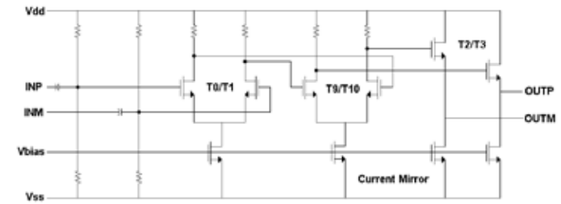

Figure 4: Differential amplifier schematic. T9 and T10 are struck with events during testing. OUTP is monitored.

SUMMARY

SEE testing of SerDes is a primary challenge of the radiation-effects community today. The need to accurately assess errors and analyze the time-domain error characteristics leads to novel testing and analysis techniques. The presented data collection technique allows the compilation of the temporal characteristics of every ion strike or laser event during SEE testing. These data are analyzed with respect to strike location in the data (or clock) cycle. This gives the designer specific information as to the location, magnitude, error type, and cycle dependence to better inform future RHBD design decisions.

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High Performance Multifunctional Piezoelectric T-Beams

by Kiron Mateti
Srinivas A. Tadigadapa
Christopher D. Rahn

INTRODUCTION AND BACKGROUND

Nano Air Vehicles (NAVs) have received considerable interest in recent years for mobile sensing applications in hazardous environments. In particular, flapping wing NAVs have been studied and fabricated for their unique potential to fly and mimic an insect, hover at low speeds, and glide like a fixed wing aircraft. The smaller dimensions, however, present many challenges in the design and fabrication of flapping wing actuators and mechanisms.

Clapping wing designs are motivated by the Weis-Fogh clap and fling mechanism used by certain insects that, on average, produce 25% more force per unit flight muscle mass than a non-clapping stroke. Micro Air Vehicles (MAVs) have been built with clapping wing mechanisms driven by electromagnetic motors with gears and linkages. The crank mechanisms used in these designs constrain the flapping amplitude based on the geometry of the linkages and can be complex and difficult to fabricate. For electromagnetic motors, resistive losses tend to dominate as size decreases, lowering efficiency at the submillimeter scale. Piezoelectric actuators, using active materials such as lead zirconate titanate (PZT), have many attractive features such as high power density, scalable efficiency, and versatility of fabrication. No piezoelectrically driven clapping wing vehicles existed prior to the authors development of a T-beam actuated NAV in [1]. T-beam actuators function like unimorph actuators, are monolithically fabricated from bulk PZT quickly and easily using a high precision dicing saw, and do not require bonding of passive layers as in unimorph/bimorph actuators[2]. The Penn State NAV (PSNAV) uses a clapping wing hinge lever mechanism to amplify the T-beam displacement and provide ~35º peak flapping stroke angle at DC[1].

In addition to large flapping stroke, NAVs require significant wing rotation in proper phase to produce lift. Many insects and NAVs passively achieve wing rotation as a result of aerodynamic loading and wing inertia. In this work, we modify the wing design of the PSNAV to include passive wing rotation. To properly predict and design wing trajectories, analytic models of wing flapping and rotation are derived, including unsteady aerodynamic wing loading corresponding to the low Reynolds numbers flow. The simulated NAV wing trajectories and thrust are validated using the PSNAV prototype.

DESIGN, FABRICATION, AND RESULTS

The NAV is powered by two closely spaced, parallel cantilevered T-beam actuators monolithically fabricated using a high precision dicing saw. These 20 mm, 85 mg actuators produce ~200 µm peak to peak free tip displacement and ~30 mm blocking force at 1V/µm DC. The PSNAV amplifies the T-beam displacement using revolute joints and hinges created by inserting 162.5 µm tungsten pins into 165 µm inside diameter medical syringes. These are attached to the T-beam actuators using 2 mm silicon extensions that ensure proper alignment and bonding. Stainless steel wing rods form the leading edge of the wing and attach to the tungsten pin joints. The wings are fabricated using 100 µm thick aluminum foil bonded to 12.5 µm thick Mylar. A 150 m*m* gap between the leading edge and the wing frame forms a flexure link which allows passive wing rotation. The wing rod is 200 µm x 600 µm x 6 cm stainless steel and connects the two aerofoils forming the leading edge. The T-beams are mounted to a custom PCB board using silver epoxy. During fabrication, wings and T-beams are set on separate micrometer stages and the leading edge of the wing rod is precisely connected to the tungsten pins under a microscope and bonded using epoxy. A photograph and zoomed in sections of the NAV are shown in Fig. 1. The PSNAV is actuated using a function generator and high voltage amplifier. Stoboscopic photos show the PSNAV producing ~30º of flapping angle (Fig. 2) and ~40º of wing rotation (Fig. 3). System dynamics are derived from lumped parameter estimations and unsteady aerodynamics at Re ~ 1000 (Fig. 4). Generalized coordinates are flapping angle θ, left and right wing rotation, ϕA and ϕB, respectively. Simulated wing trajectories accurately predict resonance frequencies as shown in Fig. 5.

ACKNOWLEDGEMENT

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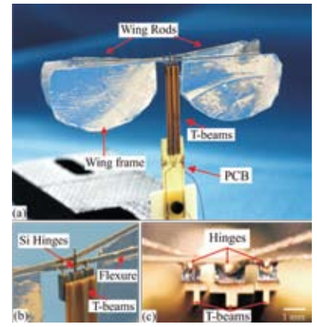

Figure 1: Photograph of a fabricated prototype Penn State Nano Air Vehicle (PSNAV): (a) side view (b) zoomed to clapping mechanism, and (c) end view

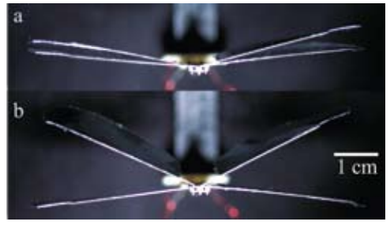

Figure 2: PSNAV in the closed (a) and open (b) position showing 30º of stroke at 9.5 Hz with 0.7 V/ µm amplitude and 0.1 V/µm DC bias.

Figure 3: Strobed images of one period of wing rotation actuated at 9.5 Hz with 0.7 V/µm amplitude and 0.1 V/µm DC bias.

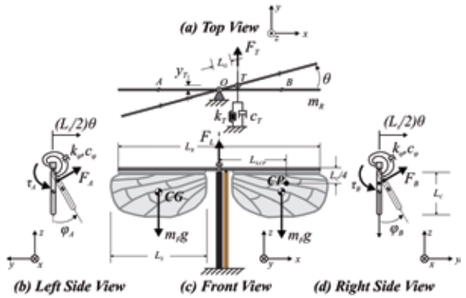

Figure 4: Schematic drawing of the PSNAV model. System dynamics are derived from lumped parameter estimation and unsteady aerodynamics at Re ~ 1000.

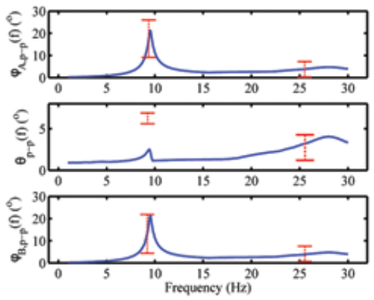

Figure 5: Theoretical (blue) and experimentally measured (red) peak to peak values of ϕA (top), θ (middle), and ϕB (bottom)

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Proceedings of ASME 2008 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference.

Improving Selectivity and Sensitivity of Anti-Terrorism Detection Equipment with FAPA-IMS-IMS

by Jonathan Dilger

INTRODUCTION

Ion Mobility Spectrometry (IMS) is a highly-utilized chemical characterization technique employed in the detection of molecules of interest due to its part-per-billion sensitivities within rapid response times. Applications include the detection of chemical warfare agents (CWAs), explosives, narcotics, and toxic industrial chemicals. Selectivity is traditionally achieved by software algorithms that assign mobility peaks as ions of potentially harmful compounds. While these algorithms can be effective in obtaining the appropriate chemical identification, they exhibit limited discrimination between the ions of interest and other ions of similar mobilities, leading to an excessive rate of false alarms. Here we investigate the improvement of CWA simulant detection selectivity with the addition of a second mobility separation step (IMS-IMS) in comparison to traditional one-dimensional separations. Here we note that this work represents one of the first combinations of an ambient plasma ionization source with IMS.

METHODS

Three G-series CWA simulants have been prepared in a dilution series from 1 mg·mL^{-1} to 0.0001 mg·mL^{-1} and introduced to a flowing atmospheric pressure afterglow (FAPA) ambient ionization source (Figure 1) coupled to a home-built IMS-IMS-MS instrument. Samples are infused through a glass capillary at a flow rate of 2.0 µL min^{-1}. Using an ion gate and ion activation region located between two mobility separation stages, identified $[M+H]^+$ ions are selected according to their mobilities and activated to generate characteristic fragmentation patterns. Fragments are subsequently separated in the second IMS dimension. Target peaks are integrated in IMS or IMS-IMS mode to determine levels of sensitivity and comparisons are drawn between the effectiveness of IMS-IMS and traditional IMS instruments.

RESULTS AND DISCUSSION

FAPA-IMS-MS DATASETS FOR FRAGMENTATION CHARACTERIZATION.

Triethyl phosphate (TEP), dipropylene glycol monomethyl ether (DPGME) and dimethyl methylphosphonate (DMMP) are established industry standards for the mobility simulation of a typical G-series CWA, Sarin gas. Spectra of each compound in FAPA/IMS-MS mode yield fragmentation patterns that are characteristic for each chemical structure. For initial studies, the [M+H]+ peak is used as the characteristic peak for the IMS analysis and the most intense ion fragment is used for each compound in the two-dimensional IMS-IMS analysis. Figure 2 displays the fragmentation pattern for TEP.

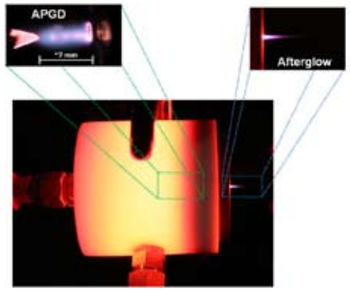

Figure 1. FAPA ionization source operating under conditions utilized for the current study. Insets show glow discharge region as well as the afterglow region. Glass capillary through which the sample is infused located ~3 mm from afterglow region and IMS entrance orifice.

DETERMINING LEVELS OF SENSITIVITY FOR CWA SIMULANTS

For IMS mode, $[M+H]^+$ ions are detected over a concentration range of 1 to 0.025 mg·mL^{-1}. Drift time minimum and maximum values have been defined for the dataset

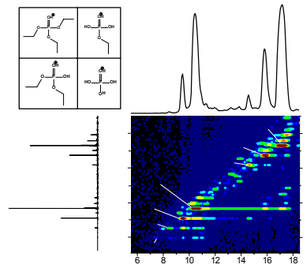

Figure 2. Two-dimensional, drift time(m/z) dot plot obtained for TEP sample. TEP precursor (A) and fragment (B through D) ion structures are shown in inset. Dataset features corresponding to dimer and monomer ions are shown in 2D plot. Drift time distribution obtained by integrating all m/z values for a given drift time is shown above the 2D plot. A mass spectrum was obtained by integrating all drift times at given m/z values shown on the left.

features and integrated areas (background subtracted) have been determined in each dilution sample. For IMS-IMS experiments, activation voltages have been determined for each CWA simulant to induce the greatest amount of ion fragmentation. Integrated values for the most energetically favored ion fragment have been used for sensitivity studies. Figure 3 shows the drift time distributions obtained upon mobility selection before and after ion activation.

Preliminary studies have indicated that for the single components TEP and DMMP, similar levels of sensitivity (Figure 2) are achieved using either the one mobility separation stage and the $[M+H]^+$ precursor ions or two mobility separations and the fragment ions. However, for DPGME the latter approach provides 102 to 103 fold improvement in overall sensitivity. This increase in sensitivity is attributed to the removal of interfering chemical species in the second IMS separation step. The improved sensitivity as well as the unique mobility profiles obtained upon precursor selection and fragmentation may add additional facets of alarm discrimination that can be capitalized upon by industry in IMS detection equipment. The analysis of the CWA simulant samples with the FAPA-IMS-IMS techniques demonstrates that higher resolution separations steps are desirable to distinguish background from reagent peaks. This problem would only be exacerbated by more complex mixtures.

CONCLUSIONS AND FUTURE DIRECTIONS

- The IMS-IMS mode can yield improvements in sensitivity by the separation of chemical noise in the second drift dimension.

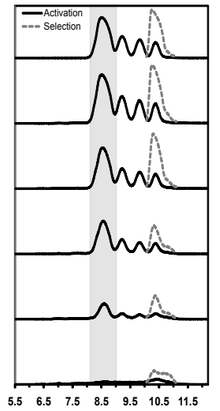

Figure 3. Drift time distributions obtained from IMS-IMS experiments for TEP. Dashed lines correspond to the $[M+H]^+$ ions selected for each analysis. The solid trace shows the drift time distribution obtained upon activation of the selected ions. The shaded area shows the peak corresponding to the fragment ion (D in Figure 1) used in the sensitivity analysis. Experiments have been carried out as a function of analyte concentration. Traces A, B, C, D, E, and F correspond to analyte concentrations of 1.0×10^{-2}, 2.6×10^{-2}, 6.4×10^{-2}, 1.6×10^{-1}, 4.0×10^{-1}, 1.0, mg·mL^{-1} , respectively.

- Selectivity of ions of interest can be greatly improved by the analysis of diagnostic fragmentation profiles resulting from selection and activation of targeted $[M+H]^+$ ions.

- CWA simulant mixtures can be mixed with known chemicals yielding false alarms from traditional IMS instruments but can be separated and analyzed on the circular drift tube.

ACKNOWLEDGEMENTS

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Concurrent Transmit And Receive Antenna Arrays

by Trevor Snow

In radio frequency (RF) and microwave systems with both a receive and transmit mode, such as electronic warfare (EW) systems, communications systems, and especially radars, the antenna aperture must be time gated between the transmitter and receiver – high transmit power would saturate receiver circuitry due to their close proximity and shared antenna elements. If this limitation could be mitigated, a system could transmit and receive concurrently, which would open up the performance capabilities for radar, EW systems, and allow for multiple systems with different functions and transmit/receive timing to share the same antenna aperture without scheduling conflicts.

A multi-function radar is one such system were many sensing functions must be intelligently coordinated and time-shared on a single antenna aperture. For relatively benign environments with low priority surveillance tasks and few targets, all tasks can be allocated enough time and resources without impacting performance. As the number of tasks increases and resource limits are reached, the radar must sacrifice some tasks in favor of higher priority tasks. To compress the time scheduling for a multi-functional radar system, sensing functions can be separated in frequency, where one frequency at a time is transmitted while all other operating frequencies are received simultaneously. Still, high power from the transmitter requires that the receiver is blanked during transmit periods. This can lead to range blind zones, especially in the range directly in front of the radar face and can be a larger problem for high duty-cycle radar systems.

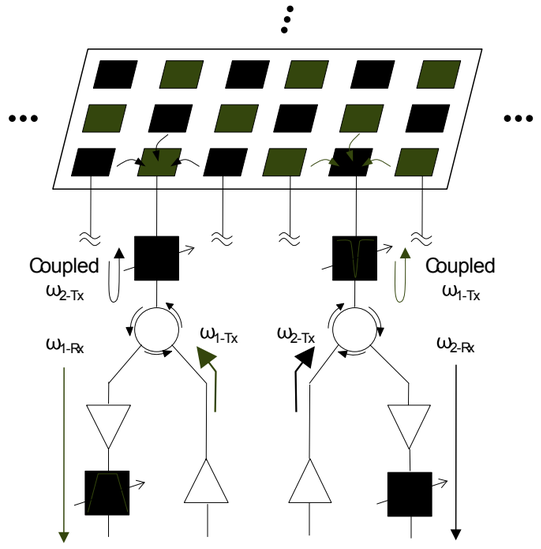

Figure 1 - Interleaved phased array operating at two separate frequencies. Tunable notch and bandpass filters reduce interference to within the dynamic range of the receiver chain.

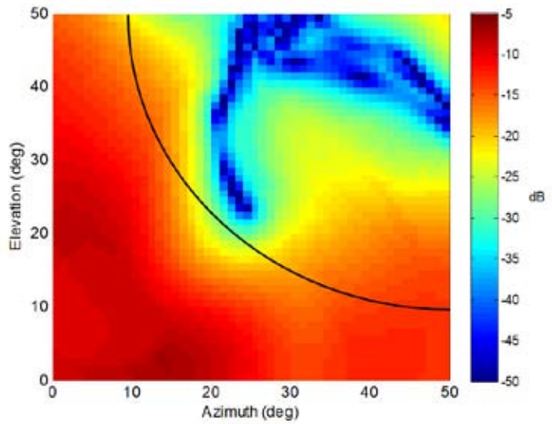

Figure 2 - Minimum coupling level into a central receiving element in a 8x8 element phased array with interleaved transmitting and receiving elements.

In a phased array antenna system, interference paths from transmitters to receivers are predominantly from mutual coupling between elements and antenna mismatch. Some energy is also coupled through whatever mechanism allows a transmit/receive module to share an antenna element between transmit and receive sources – usually a T/R switch and/or circulator. To enable the receiver to operate in the presence of high transmit power on a phased array, interleaved array elements can be configured with tunable bandpass and bandstop filters as depicted in the following figure. By creating a checkerboard mesh of what is effectively two separate and independent phased arrays operating a two different frequencies, tunable filters can prevent the front end amplifier in the receiver from saturating due to power from adjacent transmitting elements. A tunable bandpass filter can further reject coupled transmit power to reduce non-linear mixing products in the receiver chain.

To understand the level of potential interference, measured S-parameter data taken on an 8x8 square patch antenna array was extrapolated to determine the total power coupled into receiving elements interleaved with transmitting elements. The level of coupling is highly dependent on the transmit frequency, scan angle and element spacing. It was shown that the coupling could be minimized for a given scan angle by selecting the optimal transmit frequency for each scan angle. This requires a radar system that is highly frequency agile and can be implemented on a digital array radar with independent frequency and phase control at each element. This coupling is visualized in the figure below. As can be seen from this figure, there are some scan angles with very large cancellation levels around -50dB and a few points at -60dB – it would be desirable to operate at these angles. However, grating lobes begin to show up at scan angles above and to the right of the marked line.

Even with these optimizations and 90dB of rejection from tunable filters, a high dynamic range receiver is required. With the demonstrated tunable filters in the full paper and coupling levels on the array, a phased array with 25W transmit elements could operate concurrently with receiving elements with 70dB of dynamic range. Emerging GaN LNAs have been demonstrated with high linearity that would serve part of this need, while additional tunable filter stages can drop interference levels to within the dynamic range.

In the full paper, the 8x8 array with contiguous blocks of elements operating at separate frequencies was also analyzed. With understanding this mode of operation, it is conceivable to have phased arrays that can dynamically allocate different blocks of elements to independent tasks at different frequencies. Further research will focus on exploiting mutual coupling effects by adaptively controlling the phase and magnitude of coupling to achieve greater cancellation levels. Alternatively, instead of minimizing coupling, it can be magnified slightly. With tighter coupling, the energy from transmitting elements into receiving elements will reflect off the notch filter and reradiate. If the phase of the reradiated power can be controlled, transmit grating lobes and side lobes can be partially filled in. Also, the ability for a single element to isolate its receiver from its own transmitter will be examined. By implementing a step-frequency waveform and tracking the receiver filters with the transmit frequency, the receiver can block out the current frequency while listening for echoes from all the previous sub-pulse frequencies in the overall waveform. Long pulses can be implemented in this fashion while only suffering eclipsing effects due to the dwell time on a single frequency.

This paper was presented at the 2010 IEEE International Symposium on Phased Array Systems & Technology, 12-15 October 2010 in Boston, Massachusetts.

ACRONYMS

A

AEIRCM: Airborne Expendable Infrared Countermeasures
AOC: Association of Old Crows
ASNE: American Society of Naval Engineers
AFRL: Air Force Research Laboratory

C

COTS: Commercial Off-the-shelf

CRADA: Cooperative Research and Development Agreement

D

DARPA: Defense Advanced Research Projects Agency

DoD: Department of Defense

E

EO: Electro-Optics

EPA: Educational Partnership Agreement

EW/IO: Electronic Warfare/Information Operations

EW: Electronic Warfare

F

FIRST: For Inspiration and Recognition of Science and Technology

FLC: Federal Laboratory Consortium for Technology Transfer

FPGA: Field-Programmable Gate Array

H

HEDS: High Energy Density Systems

I

IBRC: Indiana Business Research Center

IDP: Innovation Discovery Process

IEEE/NPSS: Institute of Electrical and Electronics Engineers/ Nuclear and Plasma Sciences Society

IP: Intellectual Property

IR: Infrared

IRCM: Infrared Countermeasure

IUPUI: Indiana University – Purdue University Indianapolis

L

Li-ion: Lithium-ion

LTCC: Low Temperature Co-fired Ceramic

M

M&S: Modeling and Simulation

M2M: Military-2-Market

MDA: Missile Defense Agency

MIT: Massachusetts Institute of Technology

N

NATO: North Atlantic Treaty Organization

NAVAIR: Naval Air Systems Command

NAVSEA: Naval Sea Systems Command

NDEP: National Defense Education Program

NICEL: Navy Infrared Countermeasure Effectiveness Laboratory

NISE/219: Naval Innovative Science and Engineering Program

NPS: Naval Postgraduate School

NRL: Naval Research Laboratory

NSWC Crane: Naval Surface Warfare Center, Crane Division

O

ONR: Office of Naval Research

OSD: Office of the Secretary of Defense

OTT: Office of Technology Transfer

P

PIA: Partnership Intermediary Agreement

PLTW: Project Lead the Way

PSO: Particle Swarm Optimization

R

R&D: Research and Development

RDT&E: Research, Development, Test and Evaluation

RF: Radio Frequency

RSIMS: Reconfigurable Signal Injection Missile Simulation

S

S&T: Science and Technology

SAIC: Science Applications International Corporation

SBIR: Small Business Innovation Research

SEAP: Science and Engineering Apprenticeship Program

SMART: Science, Mathematics and Research for Transformation

SME: Subject Matter Expert

SPAWAR: Space and Naval Warfare Systems Command

STEM: Science, Technology, Engineering and Mathematics

STTR: Small Business Technology Transfer

T

T/R: Transmit and Receive

T2: Technology Transfer

TPOC: Technical Point-of-contact

TTIPT: Technology Transfer Integrated Planning Team

TTCP: The Technical Cooperation Program

U

USI: University of Southern Indiana

USI-CAR: University of Southern Indiana's Center for Applied Research